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By

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A THESIS

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ABSTRACT

Forecasts serve many useful purposes within the highly capital intensive telecommunications industry. The specific function of the forecasting system outlined herein is to forecast the net annual gain in the subscriber loop demand to enable a telecommunications company to optimally add additions to the system.

The model utilizes two different approaches, one for the short range forecast, and one for the long range forecast. The short range forecast is for a period of three years and is based on a combination of opinion polling and time series analysis using the Box-Jenkins methodology. For long range forecasting a logistics model is used to forecast the maximum development level within the switching center area and the time of its ocurrence.

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CHAPTER I

INTRODUCTION

1.1 Purpose

The purpose of this study is to design a computerized system for forecasting telecommunications demand within an integral system (i.e. a city).

A reliable forecasting model acts as a basis for:

(1) budgeting;

(2) conversion of costs into corresponding rate structures;

(4) monitoring costs for comparison purposes between companies;

(5) the organization of cost data for optimization studies; and

(6) manpower planning

The model is designed to:

(1) provide long range and short range forecasts of telecommunications demand for an integral system (i.e. a city);

(2) be compatible with existing plant and both current and future technology;

(3) provide flexibility to accommodate changes; and

(4) result in a minimun cost to operate.

1.2 Background

The design of a total system for a telecommuncations industry involves four major subsystems (23). They are:

(1) demand;

(2) physical plant;

(3) the costing of physical facilities; and

(4) the rate structure.

Their interrelationship is shown in Figure 1.1. A major objective of any carrier should be to design an optimization model for each of these subsystems, and to integrate these subsystems into a total integral system.

The telecommunications facilities consist of a physical network that allows verbal and data communication between users of the system.

The telecommunication plant should be classified under two major headings:

(1) support facilities (service and administration);

(a) land;

(b) buildings;

(c) office furniture and equipment; and

(2) operating facilities;

(a) subscriber station equipment;

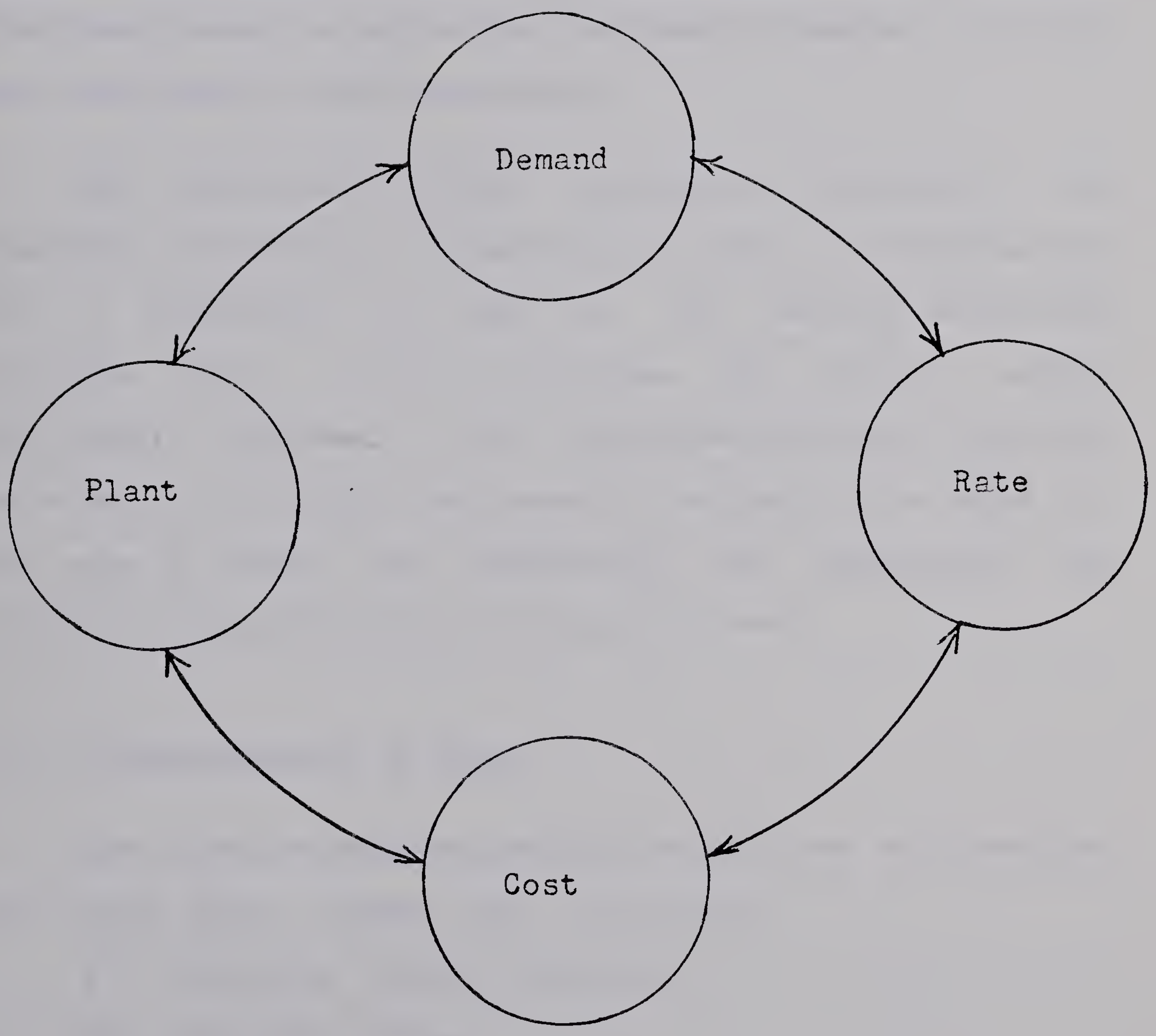

Figure 1.1 The Total System for The Telecommunications Industry

(b) outside plant facilities; and

(c) central office facilities.

The support facilities include all physical facilities necessary to perform the administrative and service functions such as accounting, corporate planning, research and development, and engineering.

The subscriber station equipment represents the equipment utilized by a subscriber at point A to communicate with a subscriber at point B. The network facilities (outside plant, station connection and central office equipment) represent the telecommunications equipment necessary to transport the message from point A to point B. For ease of costing and developing rate structures, the following classifications of plant are used.

1.2.1 Classification of Plant

The total telecommunications network can be classified into seven major classes (23). They are:

(1) subscriber station equipment;

(2) subscriber loops;

(3) local switching (local exchange switching centers);

(4) exchange trunking (local inter-exchange trunks);

(5) toll connecting trunks to local exchange (connecting trunk lines between toll switching centers and local switching centers) ;

(6) toll switching (toll exchange switching centers);

and

(7) toll trunking (connecting trunks between toll switching centers).

The importance of measuring the interaction between these subsystems with some degree of accuracy in order to develop a near optimal telecommunications system cannot be overemphasized. For example, the gross local additions per telephone are approximately $1300.00. In addition, a nominal saving of one percent in capital costs, based on the present rate of telecommunications capital investment in Canada, represents in the order of $20,000,000 or for a city of 500,000 people an annual saving of at least $400,000 can be expected. A one percent saving in capital budgeting costs with no loss in service level is a conservative estimate of the possibilities open to each individual carrier.

1.2.2 Optimization Within the Total System

The optimization of the total Canadian communications system, including all local and toll networks, as an individual entity does not appear to be practical within the realm of existing computer technology. However, fortunately a high degree of optimization within the total system is possible by considering each city or rural community as an integral system with the toll connecting facilities being the tie nodes with other integral communications systems

throughout Canada and the world.

The switching center area is considered the critical building block within an individual system (a switching center area or an exchange area is the area serviced by an individual switching center). Therefore, all information with respect to the design of a near optimal network such as forecasting data and physical facilities will be generated by switching center area. The interaction between other individual switching center areas within the system (i.e. a city) and the impact of each switching center area on the toll system must be carefully monitored and converted into capital and operating budget requirements. Figure 1.2 is a schematic representation of a switching center area as a building block (23).

There are four basic planning units that should be considered in the development of a switching center. They are:

(1) lines (subscriber loops);

(2) hundred call seconds (CCS);

(3) call attempts (CA); and

(4) grade of service.

In actual practice knowledge of the number of subscriber loops and the type of subscriber station equipment tied to these loops is sufficient to design a system. The planning units CA and CCS are directly related to the number of lines and the type of terminal equipment.

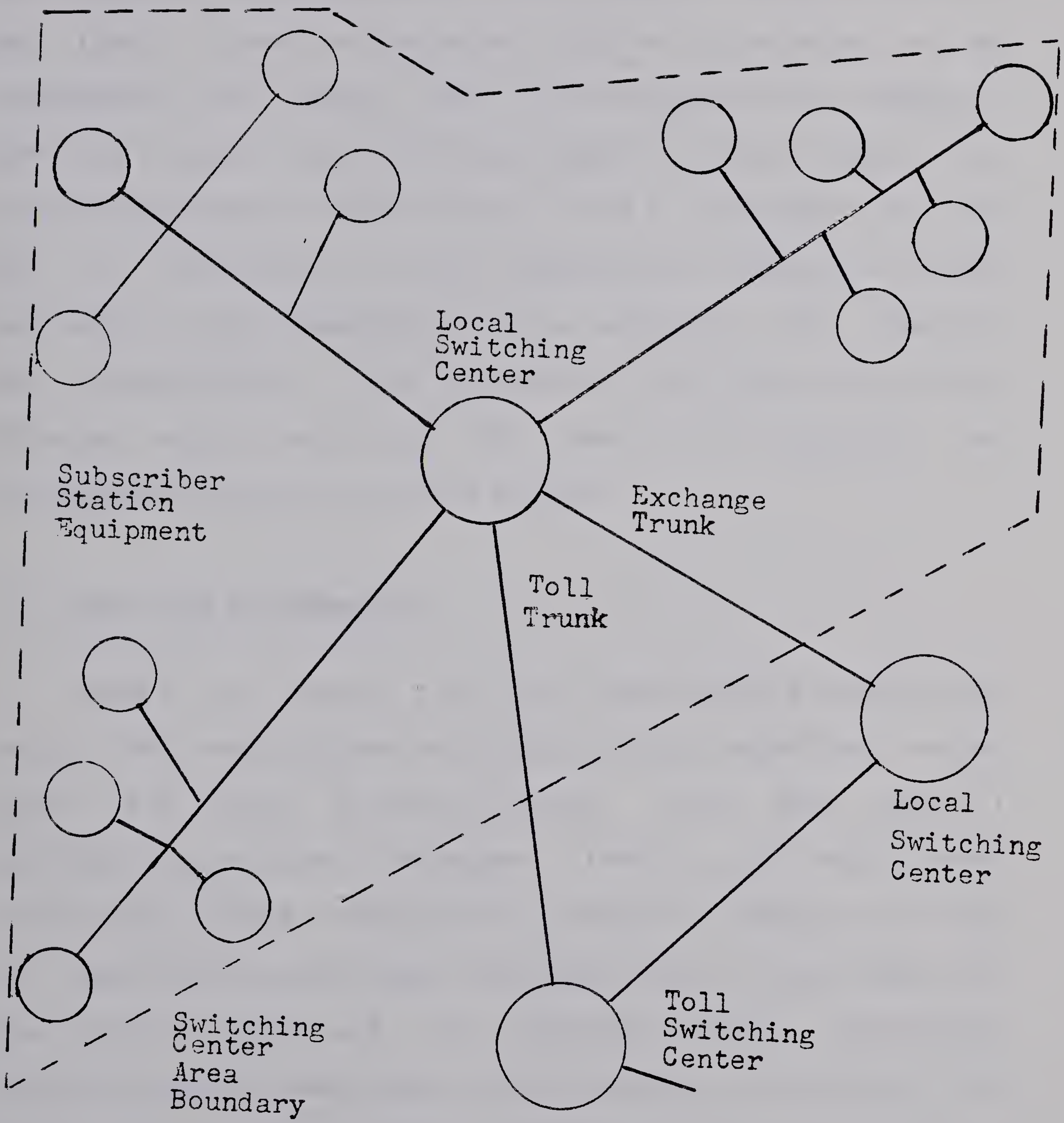

Figure 1.2 The Switching Center Area as A Building Block

For example a PABX system generates on an average 11.5 CCS per line. Grade of service can be considered as an endogenous unit being under the control of the company. Thus the forecast of subscriber loops is a major input to an optimal placement of facilities. From a knowledge of the type of subscriber station equipment and subscriber loops dedicated to the equipment, one can arrive at the planning unit requirements. The forecasts for these four basic planning units can then be used to optimize the telecommunications facilities design.

1.3 Scope and Methodology

Figure 1.3 shows the flow chart for the forecasting model. The total system is divided into switching center areas, the basic building blocks. Both long range (including the maximum development level) and short range (three year period) forecasts of demand for subscriber loops are made for each of these switching center areas using the time series data and the exogenous data. Individual switching center area short range forecasts are allocated to local areas within the switching center area from a knowledge of city development plans.

The forecasting technique recommended in this report uses a combinatorial approach. For short range forecasting a combination of quantitative technique (the Box-Jenkins methodology) and a qualitative technique (opinion sampling)

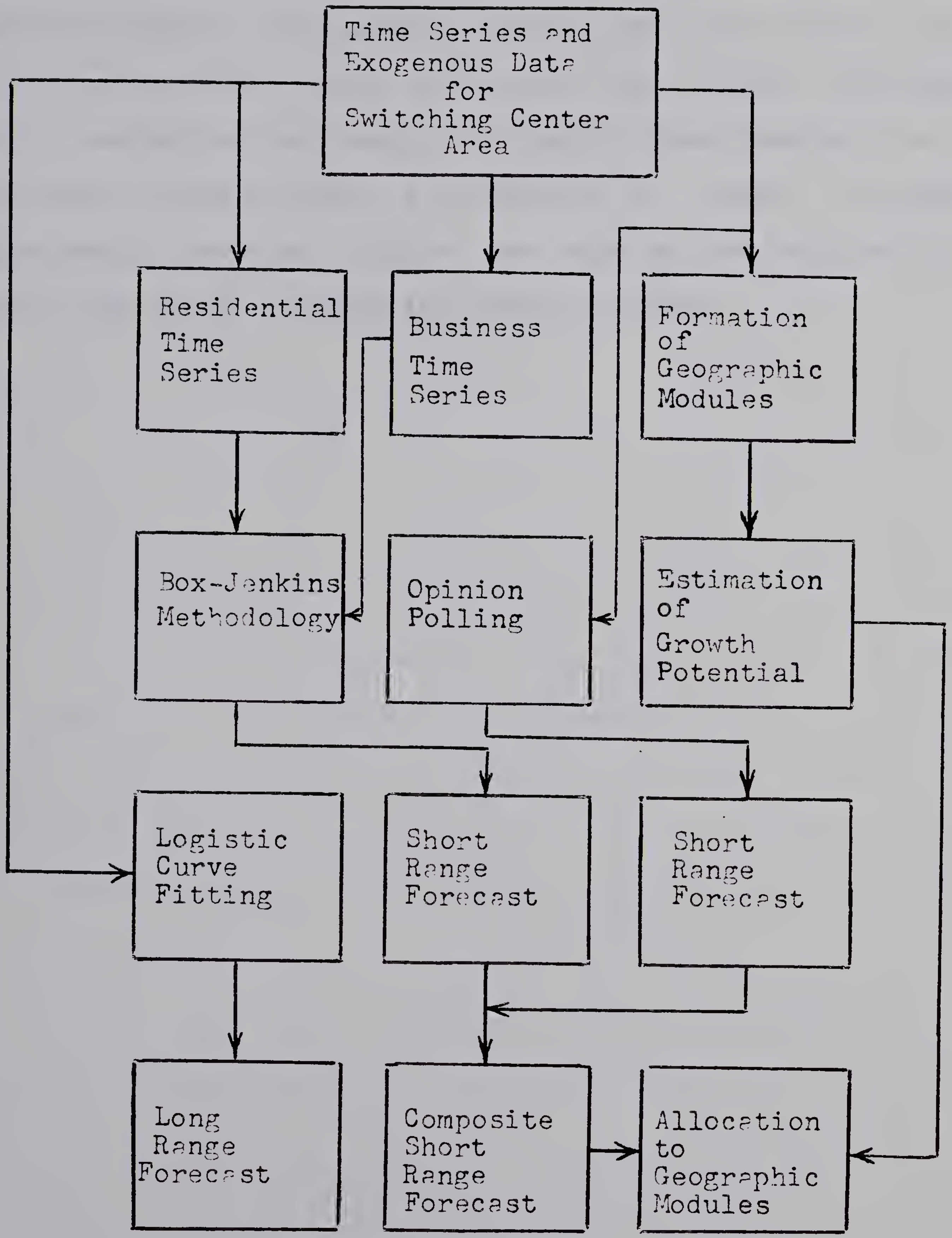

Figure 1.3 A Flow Chart of The Forecasting Model to predict Telecommunications Demand

is used. For long range forecasting a logistic model is used to forecast the maximum development level and the time of its occurrence. These estimates are further modified using subjective judgement. The short range forecast for a switching center area is allocated to small regions (geographic modules) within the area on the basis of the growth potential of these individual modules.

CHAPTER II

THE NATURE OF TELECOMMUNICATIONS DEMAND

Forecasting the telecommunications demand requires attention to its peculiar nature . An important concern in this problem is the need to recognize the different categories of demand. Telecommunications demand is not a simple variable. It is a complex phenomenon made up of components having different characteristics. It includes demand for telecommunications equipment used by the subscriber, increase in telecommunications traffic, additional requirements of outside physical plant and switching centers, demand for connects and disconnects, additional manpower requirements, and additional revenues and investments.

Owing to the different characteristics of the telecommunications demand, forecasts have to be made separately for:

(1) company revenues;

(2) total messages;

(3) telephone demand;

(4) telephone usage; and

(5) manpower requirements.

The forecasts of revenues, expenses and the construction program for a telecommunications utility dictate the need to raise new capital. The forecasts of telephone demand, telephone usage, and total messages are needed to engineer new systems. The forecasts of manpower requirements are prerequisites of manpower planning. These variables are sufficiently different to warrant separate statistical analysis. Each application gives rise to its own forecasting needs.

Local area main station forecasts are needed for a period of approximately three years into the future because of the lead time required to design, manufacture and install an addition to an existing plant. However, for manpower planning purposes, monthly changes in both inward and outward movement are particularly important. The inward station movement in a given month is the sum of residence and business main telephone installations, extension phone installations and some minor categories in that month. The outward station movement consists of removal and disconnects in these categories.

This report is tuned to the problem of forecasting net gain in the yearly demand so as to enable a telecommunications company to optimally add additions to the system. Therefore, monthly connects and disconnects are not analyzed. We are interested in net line growth and not connects and disconnects. Monthly telephone movement series

typically have a very strong twelve month (i.e. annual) seasonal pattern. In addition to this there is in many cases a less strong but significant three month seasonal pattern. Accurate forecasts of telephone gain are important inputs for both short- and long-term planning. However, this does not mean that monthly forecasts of telephone movement should be ignored. They are particularly important for scheduling the installation forces, ensuring an adequate supply of telephones and associated facilities . Besides, they are a key indicator of the company's business.

2.1 Components of Telecommunications Demand

The subscriber station equipment, also called the terminal media, can be generally classified into seven categories:

(1) telephone;

(2) voice grade data terminal using direct dialing;

(3) video telephone or T.V.;

(4) high speed data terminal;

(5) digital telecommunication terminal;

(6) transaction teletypes, etc; and

(7) special data communications (computer, data banks, etc.).

Telecommunications service is further divided into two categories:

(1) residence; and

(2) business (including public sector and government). These categories cannot be aggregated owing to their different charateristics. In addition, the demand in each of these categories and other terminal media can be subdivided into four subcategories:

(1) basic growth;

(2) customer movement;

(3) replacement; and

(4) special programs.

Basic growth demand is determined for the most part by the expressed or reasonably expected requirements for the telecommunications services. These requirements are a function of the general economic climate , the demographic pattern of customers, and the package of service offered. This demand appears as a requirement for new capacity on the network and a request for additional telecommunications hardware for the provisioning of both local and inter-city service. Some 55 to 60 percent of the construction program is invested in this component.

Customer movement triggers the demand for relocating the telecommunications equipment for those who change their physical location (within the territory). This factor may seem like a trivial item but almost two million existing telephones were disconnected and reconnected in 1976 in the total Bell Canada system simply to meet the demand of customers who relocated. Once again the need for forecasts

of monthly connects and disconnects need not be overemphasized. Some ten to fifteen percent of the investment is spent in this area of service. Most of this money goes into operating wages.

Replacement of retired or damaged plant and equipment amounts to some three to five percent of the total expenditure.

Special programs constitute the remaining portion of total telecommunications demand. These programs are designed to improve service, to introduce new equipment in order to increase efficiency, and to incorporate technological innovations. Some of these programs may be directly related to a unique form of demand, such as government communications and satellite communications.

2.2 Characteristics of the Components of Demand

New residential telephone demand is closely related to new household formation. While it is true that demand for a second mainstation within the same household is rising, this demand is still very small as compared to the demand generated by new households. In the housing market, mortgage interest rates are an important determinant of demand. Interest rate elasticity has been used in forecasting the demand for housing construction. Studies have indicated that interest rate elasticity of residential housing demand is about -0.15. Residential telephone demand

is also sometimes sensitive to price, though slightly. However, there are indications that demand for telephone service is characterized by strong habit formation. The overall trend of residential gain is fairly regular. The residential telecommunications demand growth is a function of two factors:

(1) dwelling unit activity; and

(2) household formation.

Dwelling unit formation is further a function of population growth, economic growth, and the migration pattern. Household formation is in turn dependent upon marriage rate, population growth and average personal disposable income.

In some areas special residential services such as multiparty telephones are provided. But they constitute a small fraction of the total residential lines. It has to be assumed that multiparty phones do not have an impact on the number of telephone lines demanded.

Business demand seems to be very much related to fluctuations in both general and local business conditions. Most processes in business and economics are very complex and, in many cases, not even well understood because of a large number of factors with complex interactions involved. For example, a firm's net income is usually affected by economy-wide factors such as the interest rate and price level fluctuaticns. For business the income elasticity for

the short run is 1.55. GNP has been used as a proxy for economic activity in the design of many forecasting systems. In the context of business telecommunications demand distinction must be made between highly telephone intensive organizations such as commercial banks, insurance companies and brokerage companies, and those which are not highly telephone intensive such as manufacturing organizations. Business telecommunications demand is also very closely related to the number of white collar workers in a given area. Though a trend does exist in the long run for business demand, in the short run business gain depicts no trend. Business telecommunications growth is subjected to many constraints of the local area and the total system, such as costraints of investment, production, fluctuations in the economic activity etc.

The business telecommunications demand can be quantified in terms cf factors such as:

(1) GNP;

(2) change in GNP;

(3) price of the telecommunications service;

(4) income of the telecommunications intensive companies; and

(5) general economic activity in the area.

In this report we are concerned with the annual line growth both in the residential and the business sector. A line is a subscriber loop connecting the subscriber to the

switching center, and is one of the four basic planning units. The forecasts of residential and business line growth form the basis for determining the remaining three planning units (i.e. CCS, CA, and grade of service). This total information can then be used for budgeting purposes.

CHAPTER III

ALTERNATIVE SYSTEMS FOR TELECOMMUNICATIONS FORECASTING

Most telecommunications companies have some system for forecasting purposes. But, many companies make little or no use of statistical techniques. Some companies, however, do use such techniques for making aggregate forecasts. But such forecasts cannot be used for detailed network and service planning, since they usually are the forecasts of dollars expended annually on a telephone system. The literature survey and discussions with the "edmonton telephones" indicate that several alternative systems of forecasting are in use to a degree by different carriers. They are:

(1) aggregate forecasting;

(2) subscriber station equipment forecasting;

(3) outside plant forecasting;

(4) market development area concept; and

(5) central forecasting.

3.1 Aggregate Forecasting

Aggregate forecasts are made for use in econometric planning models which attempt to interrelate the economics

of demand, production, and finance into a framework at the corporate level. The demand for telecommunications service is determined by the state of the national economy, demography, prices and consumer tastes. These interrelationships are represented by a forecast module. One such module has been developed at the Bell Laboratories (12). To avoid unit specification and service aggregation problems, demand is measured by a surrogate value index measure of output for each service. This surrogate value is derived from revenues as follows:

$R_{it}/P_{it}=Q_{it}$ = a measure of the quantity demanded of service i at time t;

where:

R_{it}=revenue from service i at time t; and

P_{it} = price index of service i at time t.

Demand equations for local service, message toll and other toll services, wide area telephone service, and private line service have been estimated using the following form(12):

$$\log(Q_{it}) = a_i + b_i \log(Q_{i,t-1}) + c_i \log(Y_{it} / P_{it})$$

$$+d \log(P_{it} / P^{*}_{t}) + n_i \log(Z_{it});$$

where:

$Q_{i,t-1}$ = habit variable;

Y_{it} = income level variable;

P^{*}_{t} = price index; and

Z_{it} = market potential index.

The past level of consumption, Q , is used as an indicator of tastes and habit formation. Unlike consumer durables, consumption of services has a strong habit forming element. Another variable used is the total telephones excluding residential extensions(12):

$$\log(TT/N)_t = 2.7170 + 0.7807 \log(TT/N)_{t-1} - 0.0167 \log(PLOC/PGNP) + 0.0846 \log(GNP/N);$$

where:

TT=total telephones, excluding residential extensions;

GNP= gross national product;

PLOC= local telephone service price index;

PGNP= implicit GNP deflator; and

N= population, 16 years of age and over.

3.2 Subscriber Station Equipment Forecasting

The forecast is provided in terms of the number of telephones by type. The residential demand for telephones is forecast by projecting the trend of main station telephones. The projection is made separately for each

switching center area. The business demand is forecast by making projections of the line growth in each of the major switching center areas in various categories such as PABX, centrex, key and multilines. The trend is modified qualitatively by judgement regarding the economic potential of switching center area. Each forecast is for a fifteen to twenty year period. Revisions are made when short term appraisals show the trend to be in error, or when building additions or commercial complex starts are made in that area. Projections of the growth of main business and residential telephones are made for an integral system (i.e. a city). These projections are used as a control by comparing the projections with the sum of individual area forecasts.

3.3 Outside Plant Forecasts

The integral system (i.e. a city) is divided into groups of switching center areas. Forecasts are made for each of these areas for a period of two to three years. No time series is used. Instead each person responsible for these areas, makes field trips and conducts interviews with real estate agents and land developers. The forecasts are made in terms of subscriber loops needed. Since the forecasts are made by outside plant engineering personnel and are used exclusively for planning outside plant, these forecasts are called outside plant forecasts. These forecasts may be heavily biased by the individual's intuitive judgement.

3.4 Market Development Area Concept

British Columbia Telephones introduced the Market Development Area concept with the aim of increasing productivity in the completion of outside plant forecasts (15). In essence it is a computerized forecast allocation system. Forecasts are made for each switching center area, using an analysis of past data and current economic conditions. A typical switching center area is composed of some forty smaller areas called Market Development Areas (MDA) which may include a few blocks or several hundred acres . Forecasts are made in terms of residential main, business main, PBX trunks, centrex, and special lines. The number of main stations are distributed to the MDA's, and then the subscriber loops are calculated for each MDA. The distribution process has two stages. The first stage is to breakdown the total predicted main stations in a switching center area to each individual MDA. The next step is to distribute grades of service. MDA's are classified according to low, medium, or high growth potential, each of which is given an appropriate weighting, generally 1, 6, and 12 repectively. This system has been in operation for about a year. The company hopes to save four man years on annual forecasts through the use of the computerized allocation system.

3.5 Central Forecasts

The so-called central forecasts are made by the commercial methods department in some telephone companies. For example forecasts are made for a total city, and individual switching center areas. The forecasts consist of the following parameters:

(1) population and household formation;

(2) terminals by area,

(a) in service, and

(b) gain (yearly);

(3) total telephones by area;

(4) business telephones for the total city;

(5) residential telephones for the total city;

(6) business telephones by area;

(7) residential telephones by area; and

(8) business telephones by type for

(a) each area,

(b) the total city.

CHAPTER IV

THE SYSTEM SELECTED FOR DETAILED DESIGN

In order to conform with the requirements of the total system to optimize to the maximum degree possible the placement of the telecommunications plant, annual telecommunications demand will be measured in terms of the line growth by switching center area. Two types of forecasts will be made:

(1) A long range forecast to estimate the potential aggregate line growth within each switching center area; and

(2) A short range annual forecast for a period of three years. The short range forecasts represent the detailed demands of small local areas (modules) within a switching center area.

The allocation of demand within a switching center area is made with the help of city development plans. The leading indicators such as household formation, industrial complex development and building starts determine the manner in which the telecommunications demand will be distributed.

4.1 The Systems Framework

The system has four subsystems:

(1) selection of forecasting modules within a switching center area;

(2) selection of a forecasting technique;

(3) selection of a demand location technique; and

(4) selection of subscriber station equipment categories.

4.2 Selection of Forecasting Modules within an Area

For an optimal design of telecommunications facilities it is very important to know precisely the distribution of telecommunications demand within a switching center area. Forecasts of demand for small areas within a switching center area are made using the data pertaining to each of these areas or modules. The alternatives available for selecting the modules for allocating demand are:

(1) using the serving area concept;

(2) using physical plant network interfaces;

(3) using homogeneity criteria; and

(4) using a combination of the above.

4.2.1 The Serving Area Concept (SAC)

The Serving Area Concept (SAC) was developed by the Bell Laboratories in order to achieve full utilization of the cable network, and ease of administration (22).

According to SAC, each switching center area is divided into service planning areas. The service planning area is the geographic area having a common gauge requirement and a common number of load points. The service planning area is further divided into smaller areas known as distribution serving areas. The criterion for establishing distribution serving areas is that in each distribution serving area the distribution plant is connected to feeder plant at a single location. These distribution serving areas could be selected as modules for forecast allocation.

4.2.2 Physical Plant Network Interfaces

A switching center area is serviced by a network of feeder and distribution cables. Interfaces are used to connect the distribution network to the feeder network, or to connect feeders to feeders, or to connect distributers to drop lines. Manholes, jumper wire interfaces, and terminal cans are some of the interfaces used in the outside plant. Thus areas serviced by plant originating from an interface such as a vault or a manhole can be specified as modules for which forecasts are to be made. Alternatively areas serviced by each feeder cable can be designated as modules for forecasting purposes.

4.2.3 Physical Division

A switching center area can be divided with the help of

natural features such as rivers, lakes and parks.

4.2.4 Homogenous Areas Concept

Some criteria of homogeneity such as subscriber mix or subscriber density can be used to create modules within a switching center area.

4.2.5 The System Selected for Detailed Design

Forecasts of smaller areas are necessary to pinpoint requirements. It is suggested that forecasts be made initially for the switching center area as a whole using the data available for that area, and the forecasted demand be allocated to the smaller areas in a manner that assures accurate forecasts. A module should have reasonably homogenous demand within itself. Major concentrations of demand such as high rises should be pinpointed and will likely represent an individual module. However, if included in a module which otherwise has a uniform subscriber concentration the remaining demand allocated to the module should be distributed uniformly to the remaining demand points throughout the module. To accomplish this objective five criteria of homogeneity are used:

(1) subscriber mix i.e. the area should be predominantly either business or residential;

(2) growth rate should be uniform;

(3) areas within the module should reach saturation

simultaneously;

(4) subscriber density should be the same; and

(5) the modules should be located outside natural barriers such as rivers, channels, lakes, etc.

The main crux of the problem is to identify these modules using the above criteria, and to allocate the total demand to each of these modules.

Figure 4.1 shows the flow chart for identifying the modules. The process essentially divides the switching center area into small and uniform areas. Initially each area is divided into predominantly business and residential strongholds. Predominantly implies the state when the ratio of lines in one subscriber group to total lines is greater than 0.75. The areas where the ratio is smaller are considered mixed and form a separate module . These areas are equally balanced so far as business and residential subscriber density is concerned. Thus, these areas are treated both as residential and business; they are virtually two different modules though having the same location. Next, each residential and business macro-module is divided into discrete areas, each having a uniform range of subscriber density. For each of these modules thus formed an index called the growth potential is calculated. It is representative of previous growth and current expectations. It is suggested that such an index be defined as:

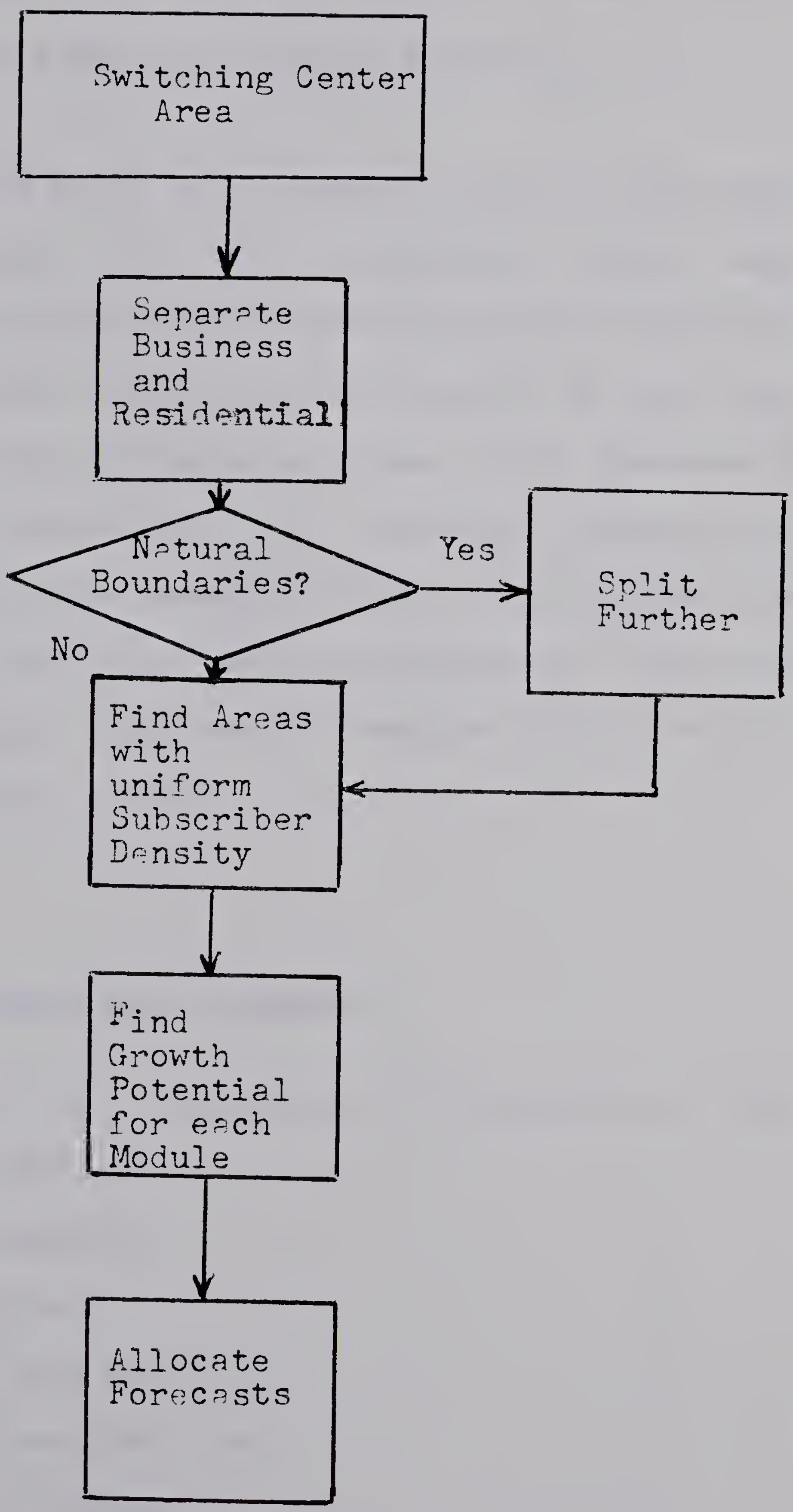

Figure 4.1 Flow Chart for Identification of Geographic Modules for Forecast Allocation

Growth Potential= (Past Local Gain / Past Total Gain)(1- Current Density/ Ultimate Density)

where local gain and total gain refer to gain in lines for the specific module and the total switching center area respectively. This factor can be modified using subjective judgement. The ultimate density is the density in that area at the time of ultimate provision of lines. The forecasted growth for each residential and business category is allocated using the growth potential index. The modules are named A, B, C, etc. and other characteristics as shown in Table 4.1 are recorded. Separate formats are maintained for residential and business groups.

4.3 Selecton of a Forecasting Technique

Many techniques are available for forecasting. They can be broadly classified as:

(1) intuitive judgement;

(2) opinion sampling ;

(3) time series analysis;

(4) correlation analysis; and

(5) combination of above.

Each technique is suitable to a particular forecasting problem. The selection of a technique for forecasting is dictated by the following criteria:

Table 4.1 Format for Forecast Allocation to Modules within A Switching Center Area.

Switching Center______________ Residential Forecast________

Module	Area (sq. miles)	Density (lines per sq. mile)	Growth Potential	Forecast

(1) purpose of the forecasts;

(2) availability and length of the data base;

(3) nature of the demand variables;

(4) knowledge about the contingent events;

(5) the forecast horizon;

(6) degree of sophistication; and

(7) cost.

Short Range Forecasting

Household telephones are necessarily goods which are retained even if the user cost is high or income is low. These variables are insignificant. The improvement in the quality of service caused by new technology such as automation etc., are strong arguments in the demand function, and since technology is still improving they will not change. The demand, therefore, depends upon the potential market, that is, the number of customers not having a telephone set.

The usual indicators of this market are the rate of household and dwelling unit formation. However, in certain cases such as high past vacancy rates and low residential activity, these indicators fail to lead the demand. An analysis of the time series furnishes the forecaster with additional insight into demand forecasting.

It is suggested that a combination of opinion sampling

and time series analysis be used in forecasting short range demand. In forecasting telecommunications demand there is rarely one technique that is superior to others across all dimensions. A combination of forecasting techniques are frequently more accurate because more information is used to compile a composite forecast.

Opinion Polling

Demand for telecommunications can undergo sudden upswings or downswings when there are abrupt surges or lulls in the local economy and construction activity. In such instances the past is expected to be a poor guide to the future activity. Qualitative methods such as opinion polling are useful in anticipating these turning points. One of the most direct and widely used methods of generating a forecast is to sample the opinions of one or more individuals who are knowledgeable in the specific area under consideration. For example in the field of telecommunications and associated areas there are many individuals who are knowledgeable with respect to the expected demand for the future services. A forecast may be derived from a general consensus arrived at from interviewing these individuals.

It is suggested that a formal interviewing program be established on a pattern similar to that of the well known

Delphi technique (6). The purpose is to make effective use of the 'informed intuitive judgment' of the individuals recognized as leaders in the particular field under question. A constructive and systematic use of the opinions can be made by assuring that:

(1) the 'experts' are selected carefully; and

(2) the communication with these "experts" is facilitated as much as possible,to eliminate to the maximum degree possible any misunderstanding and thus misinterpretation.

The traditional method of achieving a consensus of experts has been to meet with these individuals collectively and ask for a statement of group position. However, this procedure is apt to give a forced compromise, more often as a result of some individuals' authoritarian attitude. The Delphi technique is designed to overcome this drawback. It eliminates 'committee activity' and replaces it with a program of sequential individual interrogation (usually best conducted by questionnaires). These questionnaires are interspersed with information and feedback based on the opinions of each individual in the group.

Two main sources of expert opinion can be identified within any given field:

(1) sources internal to the organization; and

(2) sources external to the organization.

The final breakdown of internal sources will vary from company to company within the telecommunications industry depending on the organizational structure. One such breakdown is:

(1) the outside plant personnel; and

(2) the marketing personnel.

The outside plant engineers are a very reliable source of the information vital for forecasting. These individuals are in touch with the 'community' and, therefore, have a feel for the trends in demand.

The marketing personnel are familiar with economic factors, migration patterns, land use plans and the advertizing thrust. Their opinions, therefore, are quite helpful in determining the demand particularly in the business sector.

Sources external to the organization are mainly the City government and the people in the real estate business. These sources are useful in indicating where future potential telecommunications demand will locate.

Once the "experts" have been selected the polling should begin in a well planned manner. A recommended procedure is:

(1) distribute the initial questionnaires, and receive the estimates of the demand;

(2) summarize the estimates and return the information

to the "experts" along with the additional information generated from responses to the first questionnaire, or demanded by the experts, and a follow-up questionnaire. The summary should state the average estimate and some indication of the range of the responses. Such an indicator could be the interquartile range which is an estimate of the middle 50% of the estimates. The experts should be asked to reconsider their earlier estimates and change them if they deem likewise. And if the new estimates are still outside the interquartile range, they should substantiate the spread with reasons;

(4) if some of the estimates still remain outside the range go to step 2, otherwise;

(5) take the median of the final estimates as representative of the consensus.

Often the convergence of estimates is achieved in three to four follow-ups. However, in cases where the convergence is far from imminent, one can discern two main distinct values emerging as central tendencies. This could be the result of two different sets of data having been distributed or two different interpretations of the same information. In such cases steps should be taken to eliminate the reasons for the misinterpretation.

The final estimates based on opinion polling should be

combined with those arrived at through time series analysis. The method of weighting the two forecasts is presented after a discussion of the time series analysis.

The construction of an appropriate time series forecasting model for an area based upon its own past history is useful not only in producing forecasts when leading indicators are not known or available, but also in providing a basis for comparison with models incorporating information from appropriate leading indicators.

Time Series Analysis

Many techniques using time series as the basis for model building are available. They can be classified under three major categories, though specific techniques by virtue of their characteristics may belong to more than one category. They are:

(1) smoothing techniques;

(2) Box-Jenkins technique; and

(3) regression techniques.

Smoothing Techniques

The rationale of smoothing techniques such as moving averages, exponential smoothing and other forms of smoothing is that demand is subjected to random fluctuations and that there is some underlying probability distribution whose

central tendency changes with time (8). The pattern is represented by the time series. The smoothing process involves distinguishing between the random fluctuations and the underlying basic pattern.

The moving average model can be represented as follows:

$$\hat{Z}_{t+1} = (Z_t + Z_{t-1} + Z_{t-2} \ldots\ldots\ldots Z_{t-n+1})/n$$

where:

$\hat{Z}_t$ = the forecast for the time t+1;

Z_t = the actual value at time t; and

n = number of values included in the average.

The difficulty with the basic moving average model is that it seems implausible that weights be assigned equally to all the past observations. Also computing a moving average forecast necessitates the use of considerable computer storage.

Intuitively it seems more reasonable to put more weight on more recent observations and let the weights decline for older observations. Exponential smoothing satisfies this requirement and eliminates the need for storing the historical values of the variable. An exponential smoothing model can be represented as:

$$\hat{Z}_{t+1} = aZ_t + a(1-a)Z_{t-1} + a(1-a)^2 Z_{t-2} \ldots\ldots\ldots\ldots$$

where $0<a<1$.

The ratio of any adjacent pair of weights is the fraction $(1-a)$ and hence is said to decline exponentially. The above equation can be expressed as follows:

$$\hat{Z}_{t+1} = \hat{Z}_t + a(Z_t - \hat{Z}_t)$$

where:

$(Z_t - \hat{Z}_t)$ is the error in the old forecast.

Forecasts are prepared by extrapolating the moving average $(\hat{Z}_t)$, that is updated at the end of each period t, into future periods, that is, $\hat{Z}_t$ is the forecast of the time series value for the period t+1, t+2 etc. The primary virtue of the exponentially weighted moving average is their great computational convenience. However, a lack of a general methodolcgy of selection among alternative models is a weakness that renders it less attractive. Based on this drawback these models are characterized as ad hoc models (19).

Box-Jenkins Technique

According to Box and Jenkins (3) there are three general classes of models that can describe the type or pattern of specific data. They are:

(1) an autoregressive model (AR);

(2) a moving average model (MA); and

(3) a mixed autoregressive and moving average (ARMA).

An autoregressive model expresses the current value of the series as a linear combination of past values that explain the current observation and an unexplained portion 'a_t':

$$Z_t = \phi_1 Z_{t-1} + \phi_2 Z_{t-2} \ldots\ldots\ldots \phi_p Z_{t-p} + a_t$$

where:

ϕ_p represents a weighting coefficient for the pth previous observation Z_{t-p}; and

a_t is the residual term.

A moving average model assumes that the current value of the time series can be expressed as a linear combination of the previous forecast errors $(Z_t - \hat{Z}_t = a_t)$:

$$Z_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} \ldots\ldots \theta_q a_{t-q}$$

where:

θ_q represents a weighting coefficient for the qth forecast error a_{t-q}.

A natural extension of 'AR' and 'MA' models is to combine the two. The general form of a mixed model (ARMA) is:

$$Z_t = \phi_1 Z_{t-1} + \phi_2 Z_{t-2} \ldots\ldots\ldots\ldots \phi_p Z_{t-p} + a_t$$

$$-\theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots\ldots\ldots \theta_q a_{t-q}$$

According to Box and Jenkins (3), for many series

encountered in practice, the use of an 'ARMA' model rather than a pure 'AR' or 'MA' model results in fewer parameters.

The Regression Techniques

These techniques depend entirely upon the past history and treat the forecast variable as a deterministic function of time. A commonly used model uses a polynomial in time (20):

$$\hat{Z}_t = a_0 + a_1 t^1 + a_2 t^2 \ldots\ldots\ldots a_n t^k$$

where the coefficients are to be determined from the past history using regression techniques. The forecasting properties of the model are determined by the degree of the polynomial k. Though the long range trend may conform to the form of the function, the short range forecast modeled on a deterministic trend cannot be relied upon. A forecast based on a deterministic function would be highly systematic and predictable, which is hardly tenable.

Technique Selected

There are many advantages to the Box-Jenkins methodology. The most important advantage is that it eliminates any need to assume a fixed pattern in the data. The Box-Jenkins approach begins with a tentative pattern

which is then improvised systematically with the aim of minimizing the error. The Box-Jenkins methodology is particularly well suited to handling complex time series and other forecasting situations where the basic pattern is not readily apparent.

Using other approaches requires that the analyst use his own experience as a basis for model development. They rely on plots and indexes which aid in identifying the presence of trends and seasonal patterns. The analyst using the Box-Jenkins approach does not arbitrarily pick a specific model but instead eliminates inappropriate models until he is left with the most suitable model.

Using traditional methods, the estimation of parameters is done on a trial-and-error basis. It involves a considerable amount of judgement on the part of the analyst. Box and Jenkins, however, present a systematic approach to the determination of the parameters.

For these reasons the Box-Jenkins approach was selected as the technique for time series analysis and short range forecasting.

In view of the distinct charateristics of the residential and business telecommunications demand, separate forecasts are made for each type of demand using individual time series. Demand for telecommunications in business seems to be most affected by economic activity and

fluctuations in economic activity. Thus, on the surface it would seem that an obvious candidate for a business forecasting model could be a multiple regression technique using GNP, price, population, etc. as the independent variables. Multiple regression is essentially a structure model, that is a set of mathematical functions which purport to represent causal relationships descriptive of the organization's environment. The model building then involves parameter inference, that is, estimation of values for the unknown coefficients from historical data on the variables to obtain an equation of the type:

$$BT = a + b\,(GNP) + c\,(POP) + d\,(PRICE);$$

where:

BT is the demand for business telephones;

GNP is the gross national product;

POP is the population;

PRICE is the representative cost of service; and

a, b, c, and d are the regression coefficients.

Thus by knowing GNP, POP, and PRICE we can forecast the business telecommunications demand. The problem, however, is that we do not know the future values of these independent variables. Therefore, one is faced with the problem of forecasting these parameters before being able to forecast the telecommunications demand. Thus, the model has compounded rather than solved the problem. This approach would amount to putting extra time and resources to use.

The Box-Jenkins model based on time series analysis is more ideally suited for short range business telecommunications forecasting than regression techniques. It has the built-in capability of responding to fluctuations and trends as may be caused by economic factors. As a matter of fact, Box-Jenkins models have been successfully used to forecast the GNP.

Combination of Forecasts

A number of alternatives are available for forming a composite forecast:

(1) averaging;

(2) historical weighting; and

(3) subjective weighting.

Averaging

A simple average of the two forecasts is taken for each period.

Historical Weighting

Sometimes equal weights may not form the best combined forecast. One alternative to simple averaging is to assign weights on the basis of past accuracy of the individual forecasting technique. Thus an historically more accurate technique would usually receive more weight.

Subjective Weighting

In the case of the absence of information on past performance or where past performance may not be repeated (for example a turning point situation) it may be more reliable to weight the forecasts based on the personal judgment of the manager. It is suggested that a systematic weighting system be introduced and that the weights be reappraised. For this purpose the performances of the individual techniques must be continually monitored. Only after the relative accuracy and trustworthiness of the techniques have been measured, will it be possible to assign weights with any more degree of confidence.

Owing to the lack of history on the performance of the individual techniques a tentative weighting has been used in this report. Weights of .7 and .3 were assigned to the forecasts using time series analysis and opinion polling respectively.

In summary, the method recommended for weighting the individual forecasts is to use a combination weighting based on the historical data and the judgment of the analyst.

Long Range Forecasting

Telecommunications is essentially a utility service and the nature of growth of subscriber lines is similar to any other utility. If the geographic boundaries of a switching

center area are not altered the growth of total lines will follow a classic logistic curve (i.e. a flattened S shaped curve) as shown in Figure 4.2. Initially there is a steadily accelerating growth which is almost exponential. This growth is followed by a linear trend to the point of saturation where the growth flattens. In every defined switching center area growth will eventually flatten owing to the upper bound placed on its population and business activity by the geographic limitations. For most switching center areas defined with the existing technology, this point corresponds to a saturation value of around 36,000 to 40,000 lines.

The annual line growth is almost devoid of any regular fluctuations such as cyclical trends. It may, however, respond with a lag to severe economic changes caused by very long economic cycles.

Forecasts in the long range tend to become sensitive for obvious reasons. Owing to the ever changing technology not much faith can be placed on long range forecasts. If one were to forecast any aspect of telecommunications demand on the basis of data available in say 1910, one would perhaps come up with a system where every housewife would be a telephone operator today. Until yesterday a switching center of size 50,000 was considered outside the realm of feasibility. Today with Pulse Code Modulator carrier technology being adopted , switching center areas of size

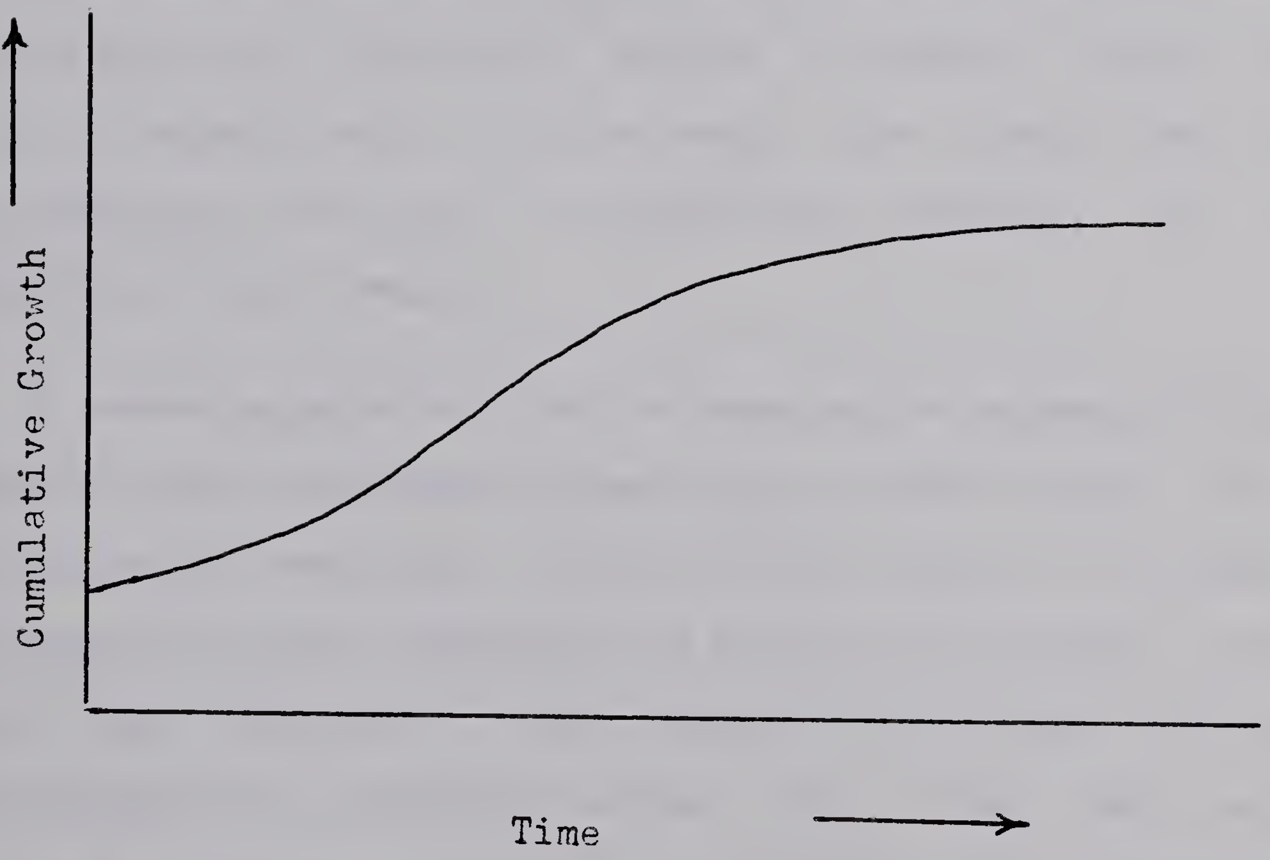

Figure 4.2 The Logistic Curve

500,000 lines are possible. However, these factors do not really pose a problem to the forecaster. For a long time to come the telephone as such will continue to be an indispensable part of our lives. The subscriber loop will still be there, perhaps not in the tangible form of a cable pair but for example as an air wave . The use of a line as a design unit will not be dispensed with. The size of a switching center area will definitely change. But the newly defined area will once again depict a growth typical of today's comparatively smaller areas. The launch level and the saturation level will be appreciably greater, but the old pattern will prevail.

A model appropriate for forecasting telecommunications demand in the long range is the logistic growth model (13). The long term evolution of the time series is usually systematic, and the saturation is bound to take place. This model can, therefore , be applied to determine the long range growth of a switching center area. The long range demand is forecast in terms of total lines i.e. residential plus business.

4.4 Forecast Location Technique

The output of the model should be compatible with the system where it is applied. The specific purpose of forecasts of line demand is the optimal placement of plant. Thus the forecast location technique is dictated by the

optimization model which uses the forecast as one of its inputs.

For example, the forecasting system can be integrated as part of a minimum cost network model within which the nodes represent an actual physical record of outside plant in place. The whole system can be placed on a grid map with grids, based on grid plane coordinates, representing demand locations. A total optimization model is flow-charted in Figure 4.3.

The Data Bank

The Data Bank stores the following information:

(1) forecast data;

(2) existing physical plant;

(3) possible carrier routes; and

(4) cost parameters.

The Master Control Unit

The Master Control Unit stores the following programs:

(1) command program;

(2) the optimization network program; and

(3) other sub-routines.

The Input Conversion System

The Input Conversion System coverts the information stored in the Data Bank into the input format required by the

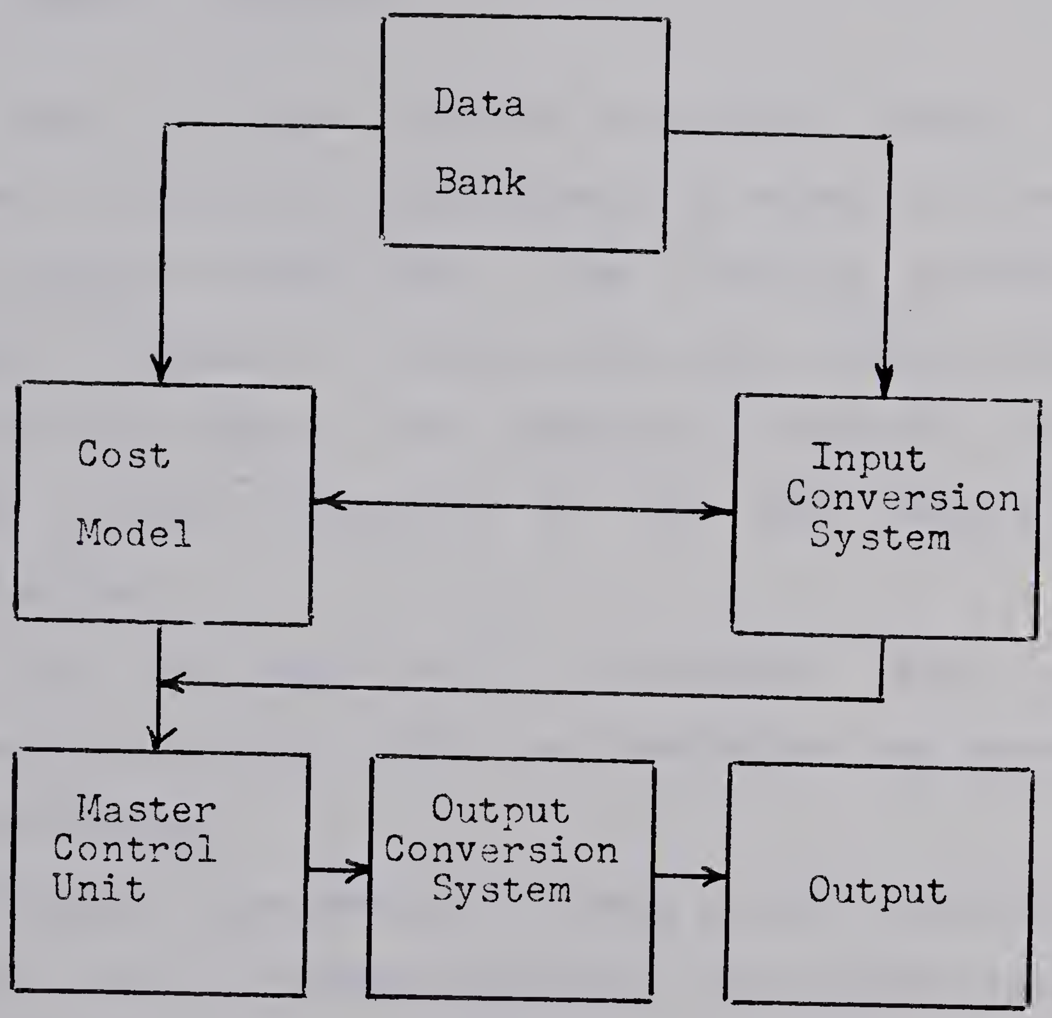

Figure 4.3 Schematic of the Total Optimization Model

network program.

The Output Conversion System

The Output Conversion System does the opposite, that is, it converts the coded output from the Master Control Unit into practical usable language.

Grid maps are drawn for each switching center area. The scale is selected appropriately in order to accomodate the plant density of the area. The distance between the grid points should be smaller than the smallest distance between any two nodes. The forecast allocated to each module is further allocated to the grid points in the following manner:

(1) find the location of potential high demand concentrations such as apartments and commercial buildings;

(2) allocate line demand to these points according to the size of these buildings, for example number of units;

(3) for the purpose of allocation of the rest of the forecast assign and locate grid points uniformly to the remaining module; and

(4) divide the allocated demand by the total number of grid points in the module.

A convenient origin is chosen. A grid map, with the nodes and the grid points is shown in Figure 4.4.

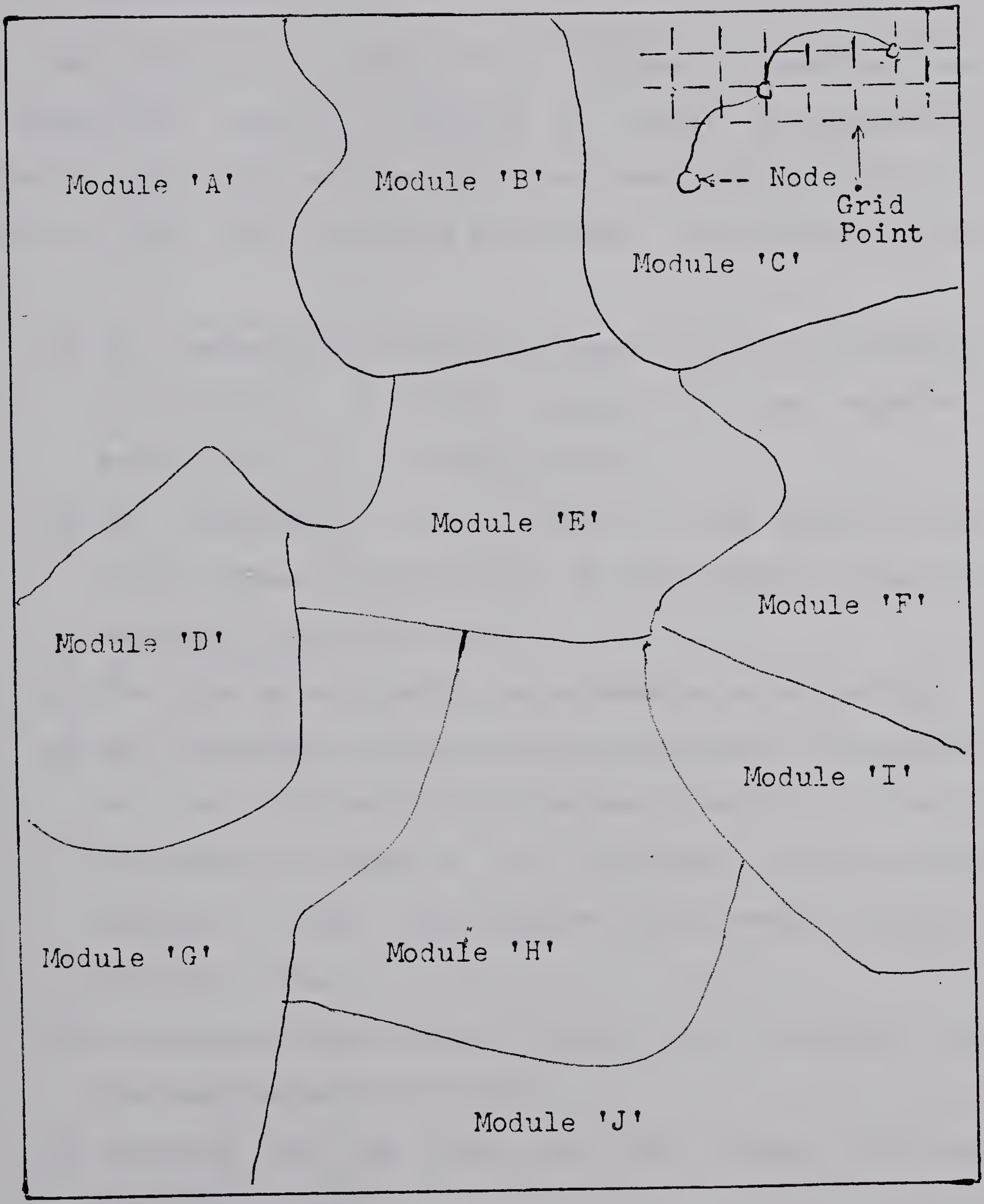

Figure 4.4 Grid Map showing Telecommunications Demand Modules

4.5 Selection of Subscriber Station Equipment Categories

The problem is to establish an optimal classification of subscriber station equipment in order to categorize demand in a way that enables it to be quantified in terms of planning units. The alternative systems of classification are:

(1) the subscriber station equipment can be classified on the basis of rates charged to the services associated with that equipment;

(2) the categories can be made on the basis of the nature and characteristics of their demand, that is business and residential;

(3) the type of equipment can be used as a criterion;

(4) the subscriber station can be classified according to the engineering limitations placed on the main distribution frame in the switching center, for example, touch tone phones, dial phones, rotary, regular, etc.;

(5) grouping on the basis of number of telephones at the subscriber's station;

(6) grouping on the basis of load placed on the facilities; and

(7) the equipment is classified on the basis of grade of service.

The criteria for selecting the best system conducive to our

requirements are:

(1) the equipment within each group must have the same technical characteristics;

(2) the equipment within each group must be identifiable with a common parameter, that is lines, stations;

(3) the load generated by the equipment within each group must be the same function of its intrinsic parameters, e.g. 8 CCS per line; and

(4) the categories should lend to ease of administration.

4.4.1 Method Selected

The design of the telecommunications carrier facilities is done from a knowledge of the four planning units mentioned earlier. The planning units, hundred call seconds and call attempts are expressed in turn as a function of lines and the type of subscriber station equipment. Every telecommunications company monitors the load placed by customers on its facilities. Generally two methods are used:

(1) the parameters CCS and CA's are measured during peak load periods (busy hour); or

(2) the average values are found from readings taken over a 24 hour period.

The busy hour values are used for the design of switching center equipment and trunking facilities. They are expressed for each of the categories mentioned in Figure 4.5 in terms of units per line. Typical values for hundred call seconds (CCS) per line are given below(these values are based on discussions with the "edmonton telephones" personnel) :

residential(individual)	1
business (individual)	1.2
key	3.75
centrex	3.5
PABX	11.5

These values also emphasize the importance of maintaining homogenous modules for forecasting purposes. A change in the mix of subscriber station equipment within a module can have a significant impact on the accuracy of the forecasts. The classification shown in Figure 4.5 is adopted for design purposes.

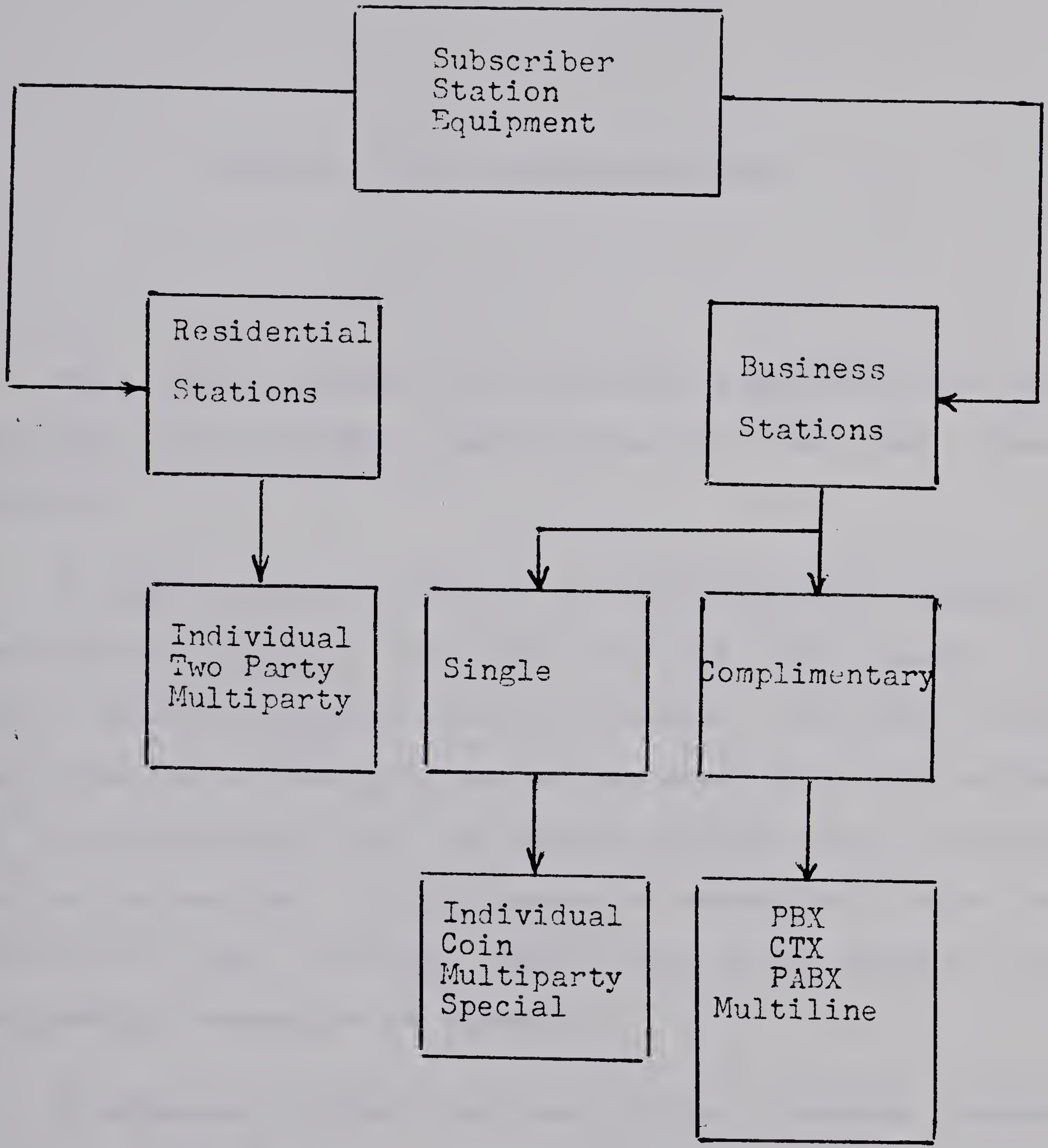

Figure 4.5 Subscriber Station Equipment Classification

CHAPTER V

DESIGN OF THE FORECASTING MODEL

The model utilizes two different approaches, one for the short range forecast, and the other for the long range forecast.

A short range forecast is valuable for many reasons, but particularly so to plan for the lead time needed to order, receive and place capital equipment. The short range forecasts for a three year period are based on a combination of opinion polling, and time series analysis using the Box-Jenkins methodology. Yearly growth of subscriber loops or lines for each switching center area in the business and residential categories is forecast.

A different approach has been used to forecast demand over the long range. The growth of lines in a switching center area follows more or less a logistic pattern. The point at which a company decides to serve the additional demand from a new switching center is determined by engineering and economic considerations. The optimum number of cumuative lines in most switching center areas at present is in the order of 36,000 lines. The long range forecasts are the basis for budgeting equipment that has a life span

of over 20 years. Switching center equipment, for example, falls into this category. Yearly forecasts for a 15-20 year period, due to their accuracy may not be any more useful than the maximum development level of the switching center area. In addition yearly forecasts are too sensitive in that range. The forecast for the ultimate size of a switching center area is also made using a logistics model.

5.1 Short Range Forecasting

The qualitative approach to forecasting short range telecommunications demand consists essentially of opinion polling. This is usually done by keeping abreast of the latest city development plans, local economic activity and other relevant factors such as migration. It is a subjective technique and is used to modify forecasts output by the time series analysis method.

The cornerstone of the time series analysis is the concept of the sequence of observations (e.g., monthly demand) constituting a time series as a realization of jointly distributed random variables. The methodology suggested by G.E.P.Box and G.M.Jenkins (3) represents a systematic approach to modeling and forecasting a time series. They have combined material and techniques, that have been available for a long time, into an approach for their application.

The basic structure of the Box-Jenkins methodology is

an autoregressive integrated moving average (ARIMA) model. It is defined as:

$$\phi_p(B)Y_t = \theta_0 + \theta_q(B)\, a_t \text{ ....} \quad 5.1$$

where:

B is the backstage operator given by:

$(B)^m Z_t = Z_{t-m}$;

$Y_t = (1-B)^d \; (1-B^s)^{d1} \; Z_t$,if d>0 and/or d1>0 , and

$Y_t = Z_t - u$,if d=0 and d1=0 ;

d=the degree of regular differencing;

d1= the degree of seasonal differencing;

s= seasonal length;

ϕ_p and θ_q are polynomials given by:

$\phi_p = 1 - \phi_1 B^1 - \phi_2 B^2 \text{ ....} \; \phi_p B^p$; and

$\theta_q = 1 - \theta_1 B^1 - \theta_2 B^2 \text{ ....} \; \theta_q B^q$;

ϕ_1 , ϕ_2 , ϕ_3 , ...are the moving average parameters;

θ_1, θ_2, θ_3, ...are the autoregressive parameters; and

Z_t is the observation at time t;

u_t is the mean of observations;

a_t is the forecast error given by $(Z_t - \hat{Z}_t)$;

$\hat{Z}_t$ is an estimate of Z; and

θ_0 is deterministic trend if any.

The Box-Jenkins modeling strategy consists essentially of three steps. They are:

(1) model identification;

(2) parameter estimation; and

(3) diagnostic checking.

The tentative procedure, as shown in Figure 5.1, is:

(1) plot the data and decide on stationarity;

(2) generate and plot autocorrelation and partial autocorrelation factors;

(3) decide on the degree of differencing;

(4) compare the differenced autocorrelation factors with standard charts;

(5) compare the partial autocorrelation factors with the standard charts;

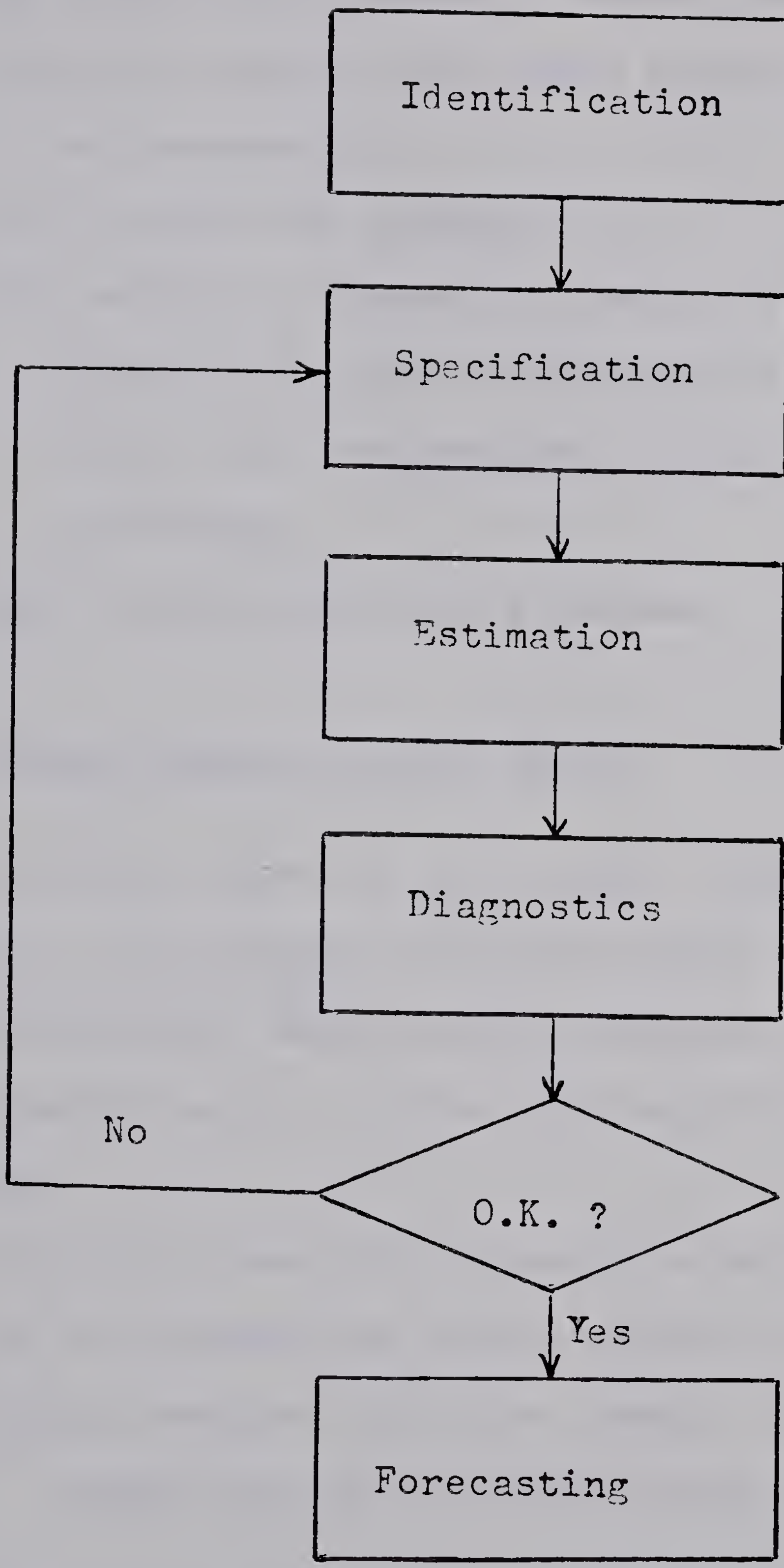

Figure 5.1 Basic Steps in Designing the Box-Jenkins Model

(6) decide which model it comes close to;

(7) start building the model by specifying the number of parameters;

(8) estimate the parameters;

(9) perform diagnostic checks, that is, decide if the model is adequate by making sure that the residual error is the smallest, if not, go back to step 3, otherwise;

(10) forecast the future values.

5.1.1 Identification of the Model

The first step in the model identification process involves identifying a tentative model (or a set of models) using the general ARIMA model described by equation 5.1. The identification of the model may be accomplished on the basis of:

(1) prior knowledge of the data pattern;

(2) an examination of the plotted series; or

(3) an examination of the sample autocorrelation and sample partial autocorrelation functions.

In actual practice, while some combination of these four factors is often considered, the sample autocorrelation and the sample partial autocorrelation factors are usually the prime indicators.

Prior research with stationary time series provides us with particular patterns of the sample autocorrelation

function and the sample partial autocorrelation function that suggest the use of either autoregressive or moving average models or a combination thereof. These distinctive patterns represent an essential feature of the Box-Jenkins methodology. Once the form of the model has been decided, one needs to determine the order (i.e., the values of p and q) of the model. Once again this is indicated by an analysis of sample autocorrelation and sample partial autocorrelation functions. Appendix A gives the definitions of sample autocorrelation and sample partial autocorrelation functions. Also given in the same appendix is the identification chart.

5.1.2 Model Estimation

The estimation of parameters is done by using the method of least squares. The criterion for selecting the values of ϕ_p and θ_q is to minimize the function:

$$F(\hat{\phi}_p, \hat{\theta}_q) = (Z_t - \hat{Z}_t)^2$$

The procedure involves using the identified model to forecast "Z" for each observation "Z" in the time series and comparing these values to determine forecast error or the residual error "a" for each period. The appropriate model coefficients are determined by selecting the set of ϕ_p and θ_q values which minimize the sum of the squared error $(Z_t - \hat{Z}_t)^2$.

5.1.3 Diagnostic Checking

The final step in the Box-Jenkins method involves checking on whether the model represents the observed time series adequately. For, example, if our model is ARIMA (0,0,1), we may wonder whether ARIMA (0,1,1) might be the more appropriate model. Or should an autoregressive parameter be added to make it an ARIMA (1,1,1) model? A simple check on such hypotheses is made by over-fitting and testing the hypothesis that the added parameter is zero, or insignificant. Another check is the estimate of variance of residuals. Yet another check is the sample autocorrelation function of the residual series. A way of looking at the process of modeling a time series is an attempt to find a transformation that reduces the observed data to random noise. If the model has succeeded in doing this, the residuals will have the properties of random numbers, and in particular are not serially correlated. Checking the model then involves examining the sample autocorrelations of the residuals. When the model is adequate, the "a" values will be randomly distributed.

G.E.P Box and D.A.Pierce (4) have suggested a statistic "Q" to evaluate the adequacy of the model. It is given by:

$$Q = n\sum_{k=1}^{K} r^2(\hat{a}) \;;$$

where:

"Q" is approximately chi-squared distributed with (k-p-q) degrees of freedom;

n is the total number of observations minus the maximum back order;

k is the number of residual sample autocorrelation values that have been calculated; and

$r_k(a)$ =the residual sample autocorrelation of the series (a) at the lag k.

The test statistic "Q" is evaluated against a "χ^2" (chi-squared distribution) with (k-p-q) degrees of freedom. When "Q" is greater than χ^2(k-p-q), this tells one that the model is inadequate and that an alternative model must be investigated.

The forecasting model herein is evaluated using both the "Q" statistic and the pattern of sample autocorrelation values for the residual series.

5.1.4 <u>The Model for a Typical Switching Center Area</u>

The time series for both residential and business demand differ considerably from one switching center to another. The difference is both in magnitude and pattern. This difference is expected since each switching center area has a unique history. For example, if one looks at a switching center area containing university residences, the time series will depict a seasonality such that a relatively

larger demand will manifest in the month of September as compared to the summer months when the number of students attending the university decreases considerably. In the context of our data base where only additional line demand is considered, the demand will be almost zero in the summer months. An area which is experiencing a rapid development will have a fairly consistent demand for a certain number of years. Therefore, every switching center area must be modeled on its own time series. Since the time series are different, the forecasting models will also be different.

The data available with the "edmonton telephones" system was used in the analysis of telecommunication demand. There was no data available on the actual demand. However, data on monthly "lines in place", referring to the subscriber loops loaded on the system, was assumed to be representative of the actual demand. As long as there are no substantial witheld orders, this assumption is valid. The actual physical plant placed is not synonymous with the lines in place. The former is usually greater than the loaded lines. In this report lines in place refer to the active lines.

In order to arrive at an adequate Box-Jenkins model the data base has to include at least 50 observations (3). This restriction is necessary to compute precise estimates of the parameters to be used in the model. This approach necessitated the use of monthly figures instead of yearly

figures. From monthly forecasts one can arrive at yearly forecasts.

Figure 5.2 shows the monthly data on residential lines in place for a switching center area. It indicates that certain lines are removed during certain periods. However, they are not physically removed. This phenomenon is called disconnects in the telecommunications parlance. Since the objective of this model is to forecast demand for new subscriber loops, the time series given in Figure 5.2 must be converted into net monthly additions after ignoring the disconnects. This is done in the following manner:

Let x and x be the number of lines in place at the end of months one and zero respectively; then the additional demand in month one is given by:

$$dx_{t1} = x_{t1} - x_{t0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5.1$$

Now if x < x , i.e., disconnects have occured, dx will be zero, and for the next month:

$$dx_{t2} = x_{t2} - x_{t0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5.2$$

Figure 5.3 shows the monthly additions for the series shown in Figure 5.2.

Appendix B shows the model building procedure for a typical switching center area. The given series is changed

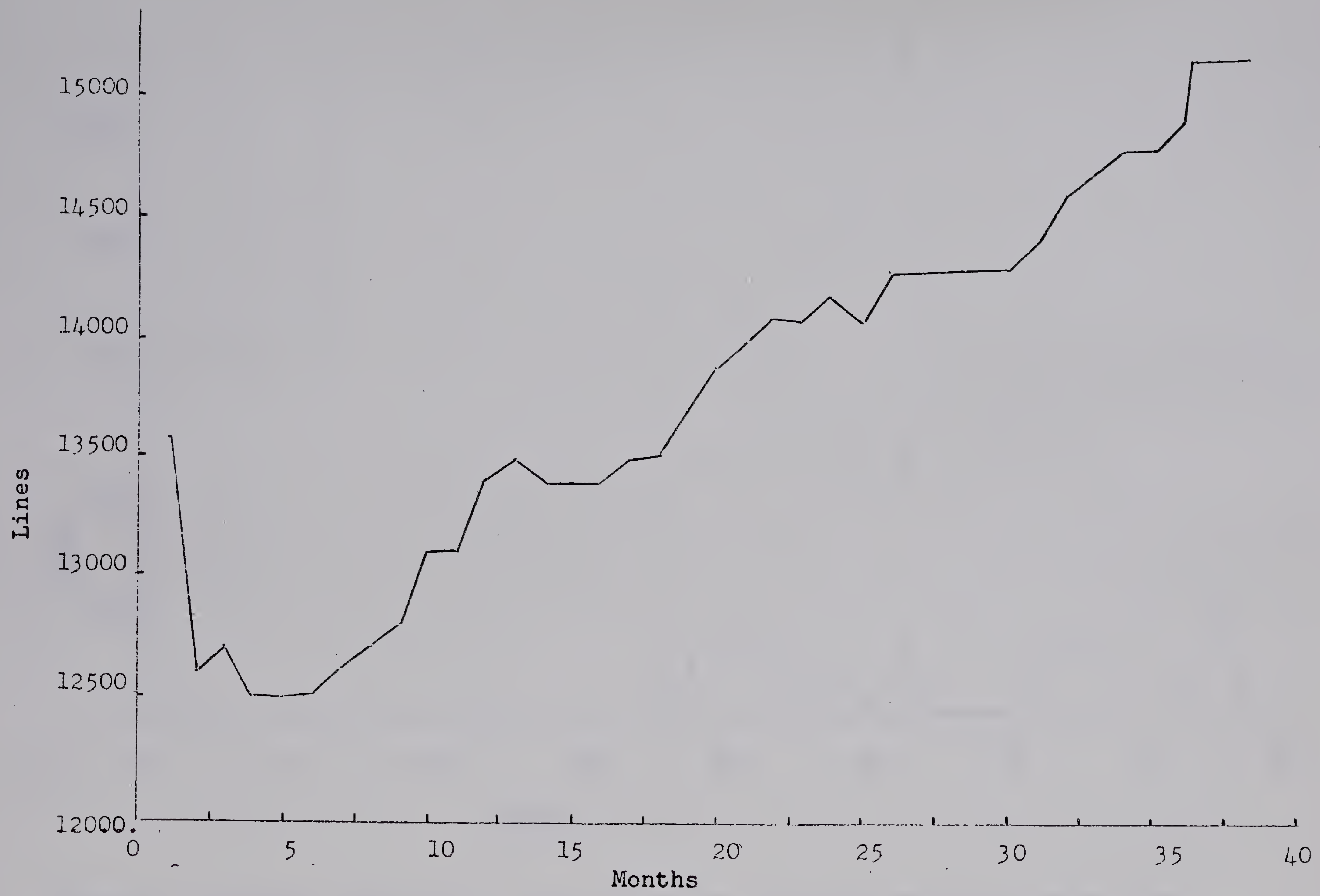

Figure 5.2 Monthly Data on Lines in Place for a Typical Switching Center Area

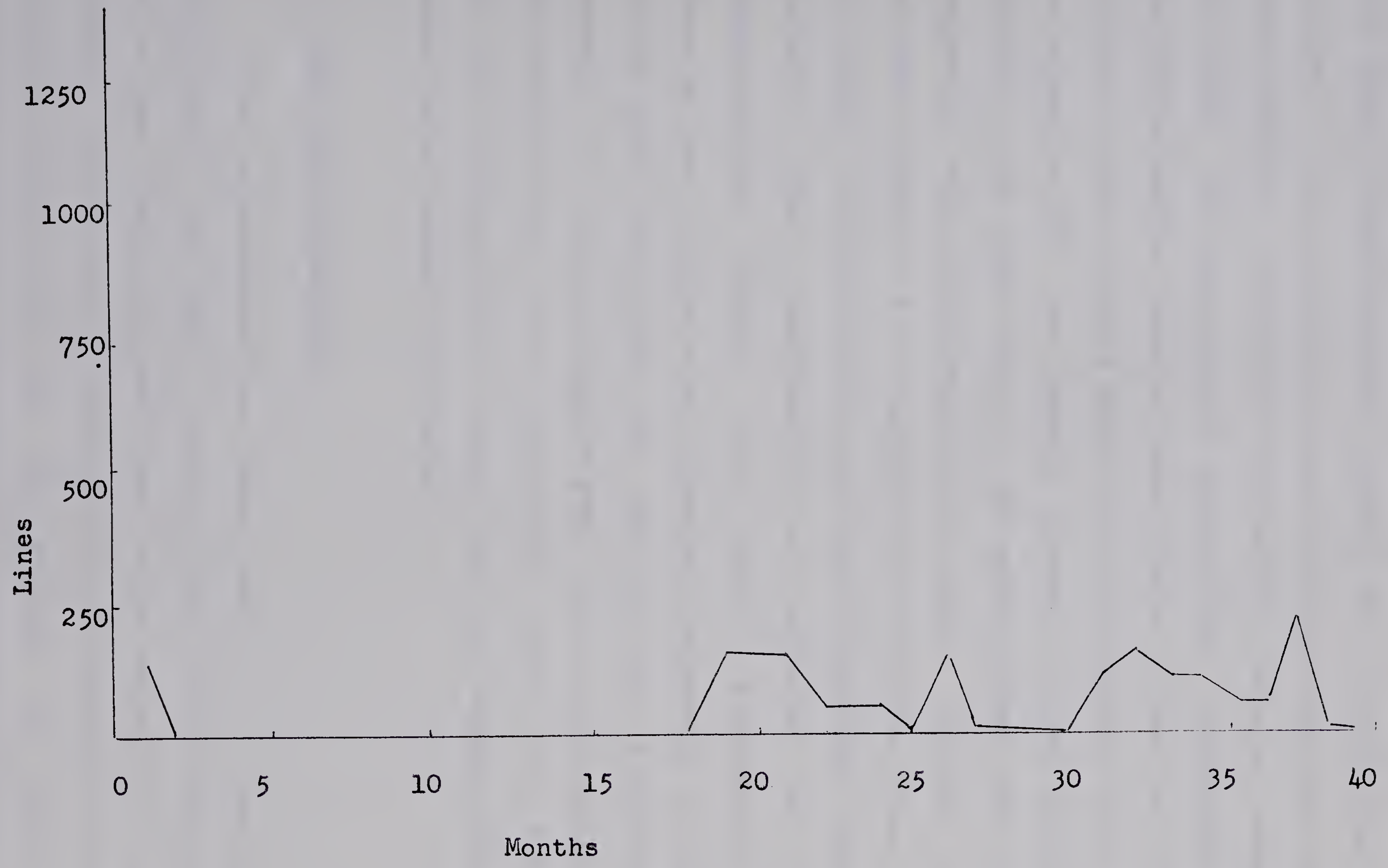

Figure 5.3 Monthly Additions to Total Lines for a Typical Switching Center Area

into monthly additions after ignoring the disconnects. A version of the program package APL Forecasting Using Time Series Analysis (1) received from the IBM computer company was used. The new series is then plotted. An analysis of the plotted series reveals three facts. There are two outlying points, that is months five and nineteen, which do not appear to fit the general pattern of the series. Secondly, the mean value of the series changes over time suggesting that some differencing is needed. Thirdly, the variance appears to be changing very little over time. In the process of identification, the first differenced series revealed more stationarity as expressed by the autocorrelation values. The partial autocorrelation function has a spike at the first lag, suggesting an ARIMA (1,2,0) model. This model was used and the diagnostics revealed it to be an adequate model for the given series. The chi-square test gave a significance value of 0.99765, and the autocorrelation values for the residual series appear to be randomly distributed.

5.2 Long Range Forecasting

Total telecommunications demand growth in a specified geographical area shows a distinct trend from the inception of the area through the development to the saturation stage. Assuming that the use of subscriber loops continues to be to connect two subscribers, and that whatever the state of technology the basic requirement of a subscriber loop, be it

a physical entity such as a pair of cable or an intangible entity such as an airwave, for planning purposes holds good, the growth of demand for telecommunications within a specified area will follow the growth of population and business within that area. Among all the series with which economics deals probably the most uniform is that of population growth. The demand for telecommunications like other utilities is in the long run dependent upon, more than any thing else, the population growth. The logistic trend or the curve of growth has been most extensively used for population and biological studies. For a switching center area the growth starts from an initial level the order of which varies. Usually it is around 2,000 to 5,000 lines. This trend is followed by a steady growth and then a decelerating growth explained by the eventual upper bound placed by the territorial limitations on the population and business activity. The exponential law applies at the beginning of the growth and must therefore be modified by another trend such as a logistic trend which imposes the ultimate limitation upon the growth. To forecast the logistic curve, after the growth has passed the transition point, is easier since the final trend toward saturation is usually smooth and regular. The ultimate growth level can therefore be fairly accurately predicted.

5.2.1 The Logistic Model

The logistic curve seems to be specially designed for the description of the growth of new industries, for population studies, and for the growth of utility services which depend upon the population growth. The curve has been subjected to numerous biological tests such as the growth of population of drosophiloe under controlled conditions and other bacterial culture (14).

As one sees from the Figure 4.2, the logistic curve may be regarded as a transition trend line intermediate between a lower initial level and an upper stable level. There is in between a point of inflection where the rate of increase of demand begins to decline.

The existence of an upper asymptote or the limit of maturity is the distinguishable feature of the logistic trend which makes it superior to the pure exponential function in the applications to economic time series such as telecommunications growth.

The curve itself is represented by the equation:

$$y = k / (1 + b.\exp -at) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5.3$$

The values of the upper and lower asymptotes are given by the lines:

$y=0$; and

$y=k$

The point of inflection is defined by the coordinates:

$$t=(\ln b)/a$$

$$y=(1/2)k.$$

The differential equation of the logistic namely:

$$dy/dt=ay-by^2 \quad \ldots\ldots \quad 5.4$$

where a and b are positive constants, shows that the growth of y is stimulated directly by the magnitude of y, but that it is checked by a factor proportional to the square of y.

Analysis of the Logistic Trend

Trends belong to the macroeconomic area, and the interpretation of their origin is thus the principal factor in forecasting the future state of the variable. A trend is that characteristic which tends to extend consistently throughout the entire period. Thus the concept of a trend depends both upon the nature of the data examined and upon the range to which it is applied. The trend of telecommunications demand in a switching center area is upward for the period it takes the demand to mature, although there may be reversals of the main movement in the short time slots of duration from a few months to a few years. It is thus seen that the definition of a trend is relative and there is no such thing as a pure trend.

The properties of the logistic curve can be discussed from a somewhat general function:

$$y=k/(1+b \exp \phi(t)) \quad \ldots\ldots \quad 5.5$$

where $\phi(t)$ is an arbitrary function. If we set $\phi(t)$ equal to -at, we obtain the logistic curve as defined by equation 5.4.

The first derivative of y as defined by equation 5.5 is found to be:

$$dy/dt=\phi'(t)(y(y-k)/k) \quad \ldots\ldots\ldots\ldots \quad 5.6$$

From this equation it is apparent that the horizontal asymptotes exist, which are the lines y=0 and y=k. These values are attained when $\phi(t)$ is respectively +a and -a. Maxima and minima of the curve between these limiting values are given for the values of t which satisfy the equation:

$$\phi'(t)=0 \quad \ldots\ldots\ldots\ldots \quad 5.6$$

The second derivative is given by:

$$d^2y/dt^2=(k\phi''(t)+(\phi'(t))(2y-k))^2(y)(y-k)/k \quad \ldots\ldots \quad 5.7$$

Points of inflection are found from the values of t which satisfy the equation:

$$k\phi''(t)+(\phi'(t))(2y-k)=0 \quad \ldots\ldots\ldots\ldots \quad 5.6$$

For the special case, $\phi(t)$=-at, no maximum or minimum value is attained though the two asymptotes exist. Only one point of inflection exists for this case and it is given by:

$$\exp(-at)=1/b$$

which yields as the coordinates of the point the values:

$t=(1/a)(\ln b), \quad y=k/2$

This is called the critical point of the logistic curve.

5.2.2 Model Estimation

A number of statistical methods have been developed for fitting the logistic curve to data, and determining the three essential parameters. One of these, due to Raymond Pearl and L.J. Reed (21), consists essentially of a preliminary estimate of the parameters from three equally spaced points and the adjustment of the parameters by computing the errors of the estimated values by means of least squares. Henry Schultz (22) has given an alternative procedure for correcting the preliminary estimates of the parameters. His solution yields the true least squares logistic in the sense that the sum of the squares of the difference between the data and the curve is minimized. A third method, "the method of increase", has been suggested by H.Hotelling(17). This method is simple to apply and yields results which are in close agreement with the other two described above.

From equation 5.7 we can write:

$$(1/y)(dy/dt)=\phi(t)(y/k-1)$$

$$\text{or} \quad (1/y)(dy/dt)=a-(a/k)y \qquad 5.9$$

Hence if we replace dy and dt by their increments Vy and Vt,

and assume that the latter is equal to unity, then we can write equation 5.9 in the form:

$$R = p + qy \qquad 5.10$$

where we abbreviate :

$$R = Vy/y,\ p = a,\ \text{and}\ q = -a/k. \qquad 5.11$$

Since equation 5.10 is a linear function in y the parameters p and q may be obtained very simply by the method of least squares from the values of R. Consequently "a" and "k" are computed from the last two equations in 5.11.

The fitting of data is then immediately accomplished by adding increments successively to any assumed arbitrary value yo. These increments are computed from the parabola:

$$Vy = py + qy^2 \qquad 5.12$$

The value of "b" can be estimated for a number of points along the range by means of the formula:

$$b = (k-y)(\exp +at)/(y) \qquad 5.13$$

The average of these values is used as the desired value.

Still a more precise and easy method is to use these values as the initial parameters, and to use them in the iterative method of non-linear least squares to arrive at a closest fitting logistic curve. A computer program is used to do this iterative procedure, since a tremendous amount of computational effort is involved.

5.2.3 Model for a typical Switching Center Area

Table 5.1 shows the cumulative annual growth of total lines for a specific switching center area. Table 5.2 shows the calculation of the parameters for the normal equation. From the totals the following normal equations are derived:

$$15p + 215287\ q = 2.03285$$

$$215287\ p + 3829960866\ q = 23199$$

From the solutions:

$$q = -.00000807$$

$$p = .2514473199$$

Thus we obtain the desired parameters:

$$a = p = .2514473199$$

$$k = -p/q = 31{,}131$$

The critical point has an ordinate k/2 equal to 15565. The year of this critical point is approximately corresponding to mark 10.

To find "b" the marks 2,6,10 and 16 were selected. The average "b" comes out to be 14.4731207. Taking 25996 as the origin and using equation 5.12 which now has the numerical form:

$$Vy = .25144731y - 0.000008076\ y^2$$

the forecasted values are found.

The forecast figures are shown in the Table 5.2.

Table 5.1 Annual Cumulative Growth of Total Lines for a Typical Switching Center Area

Year	Cumulative Growth
1961	2797
1962	3259
1963	4604
1964	5762
1965	7177
1966	8908
1967	10394
1968	11965
1969	12993
1970	14340
1971	17444
1972	20030
1973	21819
1974	23251
1976	25996

Table 5.2 Calculation of the Parameters of Logistic Curve

PARAMETERS OF THE NORMAL EQUATION

OBSERVATIONS	CHANGE	INVERSE OBSERVATIONS	R=DY/Y	OBSERVATION SQUARES
2797.0	0.0	0.000357525920629	0.0	7823209.0
3259.0	462.0	0.000306842589751	0.141761243343353	10621081.0
4603.0	1344.0	0.000217249619813	0.291983485221863	21187600.0
5762.0	1159.0	0.000173550850399	0.201145410537720	33200640.0
7177.0	1415.0	0.000139333983559	0.197157561779022	51509328.0
8908.0	1731.0	0.000112258643916	0.194319665431976	79352464.0
10394.0	1486.0	0.000096209351549	0.142967045307159	108035232.0
11965.0	1571.0	0.000083577099875	0.131299614906311	143161216.0
12993.0	1028.0	0.000076964519357	0.079119503498077	168818048.0
14340.0	1347.0	0.000069735006974	0.093933045864105	205635600.0
17444.0	3104.0	0.000057326301307	0.177940785884857	304293120.0
20030.0	2586.0	0.000049925112332	0.129106283187866	401200896.0
21819.0	1789.0	0.000045831614648	0.081992745399475	476068608.0
23251.0	1432.0	0.000043008902843	0.061588745564222	540608768.0
24549.0	1298.0	0.000040734856817	0.052873842418194	602653184.0
25996.0	1447.0	0.000038467456532	0.055662408471107	675791872.0

SUMMATIONS OF THE ABOVE

215287.00	23199.0	0.001908541830299	2.032851386815310	3829960866.00

FORECAST BASED ON LOGISTIC ASSUMPTION (FORECAST ORIGIN YEAR 1977)

1	27173	2	28041	3	28741	4	29296
5	29730	6	30067	7	30325	8	30523
9	30673	10	30786	11	30872	12	30937
13	30985	14	31022	15	31049	16	31070

A computer program was written to calculate the various parameters and the forecast equation. The listing of the program is given in Appendix C.

CHAPTER VI

APPLICATION OF THE MODEL

The city of Edmonton was selected to serve as an example to illustrate the use of the model for forecasting telecommunications demand in the short range, and to forecast the potential aggregate line growth over the long run. The telephone service for the city is provided by "edmonton telephones", a city owned company.

6.1 The Lendrum Switching Center (Edmonton)

The Lendrum switching center area is over fifteen years old, and therefore a good data base exists for this area. The length of the data base also renders it amenable to logistic model building. The data also exhibits a number of characteristics typical of growth of demand for a utility, such as seasonality, increasing trend and non-stationarity. Therefore, it was considered a good example for both model building and testing the performance of the model.

6.1.1 Short Range Forecast

Tables 6.1 and 6.2 contain the listing of business and residential lines in place on a monthly basis. Both

business and residential series are transformed into the monthly demand, after ignoring the disconnects. Tables 6.3 and 6.4 show the monthly demand. The seasonal nature of the residential series is quite apparent. During the months of April, May and June the data indicates a net zero increase in demand. This is explained by the trends in construction activity. Normally houses become available for occupation toward the end of this period. However, in some years particularly 1965, 1966, and 1967 the demand during the period April-June is not negligible. This demand was due to a lower residential activity in the past, reflecting a high vacancy rate. During this period (1965-1967) the number of installations increased with the increasing movement not related to growth.

The business series does not show distinct seasonality. This area is predominantly a residential area. However, as can be noted from Table 6.3, the share of business lines has gradually increased from the January 1965 figure of 4.8 percent to the August 1977 figure of 18 percent. This is mainly due to recent commercial development.

The approach to identification, estimation, and diagnostic checking of the forecasting models for these two series is the same as outlined in Chapter V. However, business series being a non-seasonal series, it was analyzed using the simple ARIMA model, whereas a special form of ARIMA model, the seasonal model was used for the

Table 6.1 Listing of Residential Lines for the Lendrum Switching Center

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1965	4378	4462	4569	4622	4661	4706	4769	4852	5005	5049	5141	5211
1966	5273	5933	6023	6128	6151	6224	6235	6333	6670	6566	6589	6612
1967	6630	6648	6755	6791	6867	6986	7151	7319	7613	7799	7889	7909
1968	7920	7945	7997	8087	8184	8288	8324	8529	8909	9023	9110	9196
1969	9252	9530	9714	9738	9759	9839	9882	9996	10192	10262	10294	10317
1970	10350	10377	10421	10453	10416	10440	10576	10639	10868	10948	10967	11019
1971	11062	11070	11569	11511	11513	11506	11589	11578	11809	11949	11998	12046
1972	12152	12227	13568	13619	13612	13623	13698	13805	14202	14323	14400	14530
1973	14860	15046	15856	15919	15942	16021	16148	16425	16892	16927	16887	16931
1974	17009	17554	17609	17483	17421	17407	17408	17683	18047	18208	18264	18288
1975	18336	18357	18419	18252	18320	18298	18341	18523	18788	19935	19094	19178
1976	19273	19350	19346	19259	19317	19336	19376	19392	195[illegible]	19678	19746	19853
1977	19969	19941	19967	19931	19961	20044	20193	20203				

Table 6.2 Listing of Business Lines for the Landrum Switching Center

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1965	225	353	469	462	465	471	478	473	463	460	475	480
1966	489	498	506	504	532	528	520	521	521	535	549	543
1967	547	551	544	552	555	564	566	556	566	567	576	971
1968	988	999	1017	1029	1028	1040	1052	1064	1086	1111	1118	1127
1969	1140	1246	1416	1452	1456	1462	1496	1496	1541	1572	1595	1610
1970	1615	1638	1658	1650	1638	1715	1773	1839	1863	1886	1904	1915
1971	1931	1950	2045	2050	2067	2071	2098	2112	2110	2132	2151	2156
1972	2186	2181	2237	2297	2323	2386	2397	2428	2448	2461	2510	2540
1973	2584	2600	2646	2701	2725	2774	2812	2859	2911	2924	2970	2968
1974	3021	3060	3095	3147	3170	3192	3232	3267	3316	3380	3436	3433
1975	3483	3508	3503	3546	3567	3638	3692	3734	3721	3783	3852	3905
1976	3978	4011	4080	4165	4241	4273	4300	4330	4387	4405	4448	4483
1977	4580	4326	4329	4392	4403	4440	4482	4482				

Table 6.3 Monthly Residential Gain for the Lendrum Switching Center

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1965		84	107	53	39	45	63	83	153	44	92	70
1966	62	660	90	105	23	73	11	98	137	96	23	23
1967	18	18	107	36	76	119	165	168	294	186	90	20
1968	11	25	52	90	97	104	36	205	380	114	87	86
1969	58	276	184	24	21	80	+3	114	196	70	32	23
1970	33	27	44	32	0	0	123	63	229	80	19	52
1971	43	8	499	0	0	0	20	0	220	120	49	48
1972	108	73	1341	51	0	4	75	107	397	121	77	130
1973	330	186	810	63	23	79	127	277	467	35	0	4
1974	78	545	55	0	0	0	0	74	364	161	56	24
1975	58	21	62	0	0	0	0	104	265	147	159	84
1976	95	77	0	0	0	0	26	16	167	119	68	107
1977	116	0	0	0	0	75	149	10				

Table 6.4 Monthly Business Gain for the Lendrum Switching Center

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1965		128	116	0	0	2	7	0	0	0	0	2
1966	9	9	8	0	26	0	0	0	0	3	14	0
1967	0	2	0	1	3	9	2	0	0	0	10	395
1968	17	11	18	12	0	11	12	12	22	25	7	9
1969	13	106	170	36	4	6	34	0	45	31	23	15
1970	5	23	20	0	0	57	58	66	24	23	18	11
1971	16	19	95	5	17	4	27	14	0	20	19	5
1972	30	0	51	60	26	63	11	31	20	13	49	30
1973	44	16	46	53	24	49	38	47	52	13	46	0
1974	51	39	35	52	23	22	40	35	49	64	56	0
1975	47	25	0	38	21	71	54	42	0	49	69	53
1976	73	33	69	85	76	32	27	30	57	18	43	35
1977	97	0	0	0	0	0	0	0				

residential series. The final models accepted on the basis of adequacy for respective series are given in Tables 6.5 and 6.6. The business model uses net line gain (=Z) after disconnects have been ignored, whereas in the residential model total cumulative gain (=Z) after ignoring the disconnects was used. The latter method facilitated logarithmic transformation used to achieve stationarity.

Figure 6.1 shows the map of the Lendrum switching center area as it existed in August 1977. As mentioned earlier the area is mostly residential. The business lines serve shops and offices distributed throughout the area with no concentrations in a given region excepting for the Southgate shopping mall. Thus, for the identification of specific geographic modules within the switching center area, no distinction will be made between residential and business allocations. That is, each module will receive both residential and business allocations.

A few inferences can be made from available development plans for the Lendrum area. Demand for residential lines will be generated by:

(1) major dwelling units, particularly city servicing of 619 lots for single-family dwelling units and 2150 lots for multiple family dwelling units in the 1978-1982 period.

(2) condominium units and apartment units.

So far as business development is concerned, the

Table 6.5 Forecast of Business Demand for the Lendrum Switching Center Area

Model Used: $(1-B)Z_t = (1-\theta_{-} B)a_t + \theta_0$

Month		Net Gain in Lines	Cumulative Growth
September	1977	37	4617
October		38	4655
November		38	4693
December		38	4731
January	1978	38	4769
February		38	4807
March		38	4845
April		38	4883
May		38	4921
June		38	4959
July		39	4998
August		39	5037
September		39	5076
October		39	5115
November		39	5154
December		39	5193
January	1979	39	5232
February		40	5272
March		40	5312
April		40	5352
May		40	5392
June		40	5432
July		40	5472
August		40	5512
September		40	5552
October		41	5593
November		41	5634
December		41	5675
January	1980	41	5716
February		41	5757
March		41	5798
April		41	5839
May		41	5880
June		42	5922
July		42	5964
August		42	6006

Table 6.6 Forecast of Residential Demand for the Lendrum Switching Center Area

Model Used: $(1-B)(1-\phi_1 B^{12})(\ln Z_t) = (1-\phi_1 B^1 - \phi_{12} B^{12})(1-\theta_{12} B^{12})a_t$

Month		Net Gain in Lines	Cumulative Growth
September	1977	332	20542
October		192	20734
November		36	20770
December		191	20961
January	1978	337	21298
February		0	21298
March		43	21341
April		47	21388
May		7	21395
June		193	21588
July		271	21859
August		223	22082
September		446	22528
October		230	22758
November		120	22878
December		89	22967
January	1979	296	23263
February		486	23749
March		227	23976
April		214	24190
May		0	24190
June		82	24272
July		192	24464
August		235	24699
September		494	25193
October		256	25449
November		130	25579
December		106	25685
January	1980	335	26020
February		510	26530
March		251	26781
April		229	27010
May		0	27010
June		99	27109
July		222	27331
August		203	27594

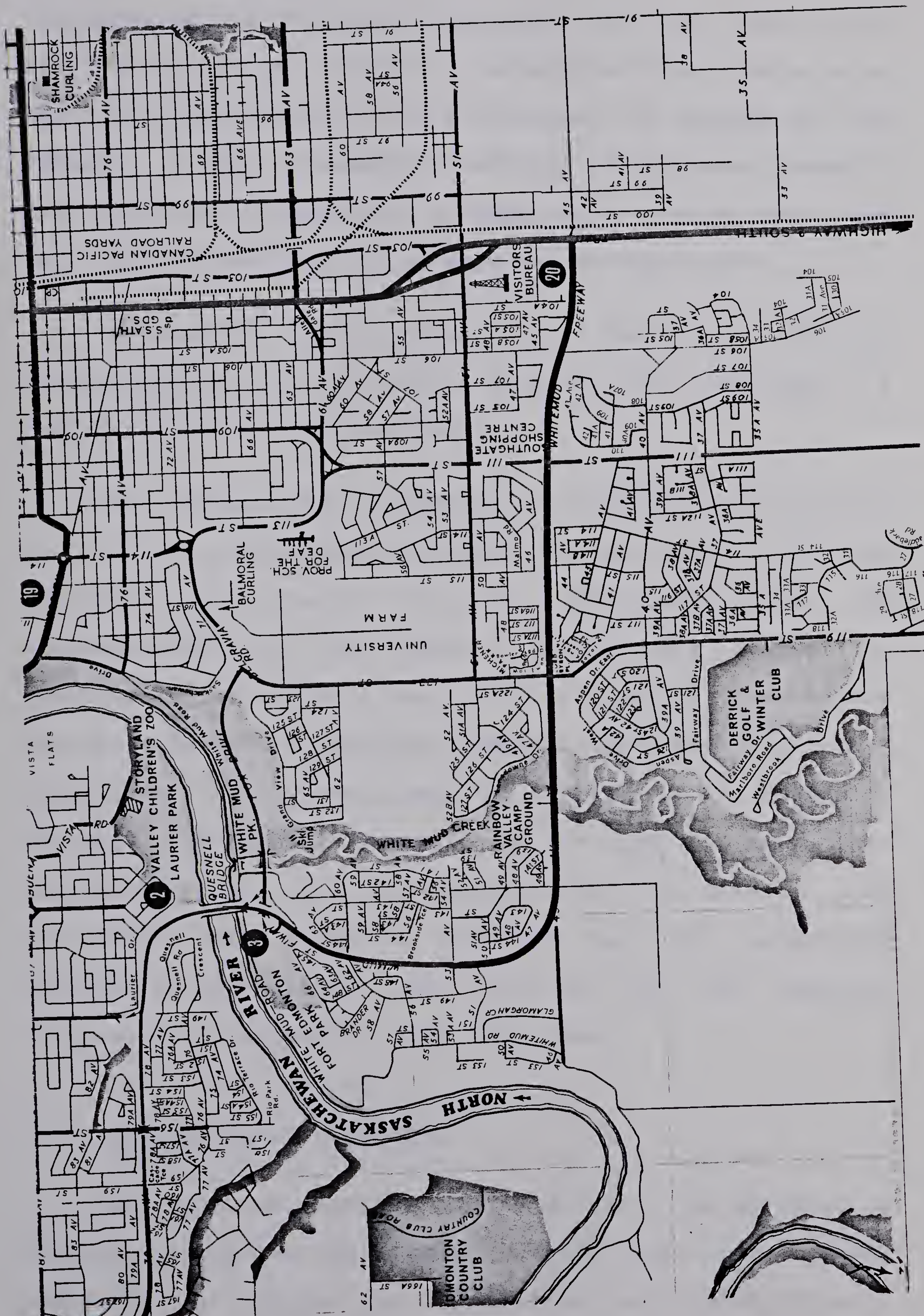

Figure 6.1 Map of the Lendrum Switching Center Area

expansion of the Strathcona industrial area has effectively lowered the line growth in the Lendrum area. There is no plan for any industrial area development for Lendrum in the future. A few communitiy shopping centers are planned. Generally the business gain is expected to remain the same for 1978- 82, and then it is expected to taper off.

In general certain areas such as Kaskiteyo, Riverbend neighbourhood and Terwellian Heights are undergoing a comparatively faster development.

The forecast for residential and business on the basis of time series analysis alone, for the next year is 1879 and 530 lines respectively. From the development plans and opinion sampling, the forecast figure with respect to business is around 400 lines . With respect to residential demand, the opinion sampling suggests that demand for about 2,500 lines will be generated. To arrive at a composite forecast tentative weights of .7 and .3 were used respectively for the Box-Jenkins and the opinion poll forecasts. The composite forecast for the residential category is estimated at 2000 lines, and for the business category it is estimated to be 530 lines.

6.1.2 Allocation of Forecasts

The forecast modules suggested for the purposes of forecast allocation are defined in Table 6.7. The growth potential as defined in Chapter IV is an indication of

future growth as reflected by past trends and current development plans. The data needed to arrive at the growth potential for the individual modules was not available. However, using data from the cable fill summary, the local gain ratio was calculated. The growth potential arrived at was further modified subjectively using information relating to major projects recently approved by the city. Table 6.8 gives a listing of major projects in the Lendrum area. Part of the forecast module "C" is currently outside of the area, and is being served by Alberta Government Telephones. Servicing for this area is planned for 1978. Development of part of the Riverbend Outline Plan Area in the forecast module "K" is presently under dispute between the developers. The settlement of the dispute is far from predictable. It is assumed that the dispute will be settled in 1978 so that servicing can commence subsequently. The growth potential factors arrived at are shown in Tables 6.9 and 6.10 which also give estimates of the parameters such as area and density. The forecasts for the residential and business categories and their allocation to modules are also given in these tables

6.1.3 Long Range Forecast

Appendix D gives the monthly cumulative growth for the Lendrum switching center area. Using the computer program shown in Appendix C, the following parameters were found:

Table 6.7 Forecast Modules for the Lendrum Switching Center.

Module	District Names	Approximate lines in place
A	Neighbourhood of Riverbend #1	850
B	Belgravia and Parkallen	4400
C	Bluequill and Yellowbird Neighbourhood	1700
D	Ermineskin	2200
E	Argyll	3200
F	Laurier Heights	900
G	Grandview Heights	600
H	Lansdowne	600
I	Allendale	3000
J	Riverbend	2000
K	Neighbourhood of Riverbend #2	500
L	Aspen Gardens	1000
M	Speedway	2000
N	Malmo Plains	1800

Table 6.8 Major Projects for the Lendrum Switching Center Area

S. No.	Name	Address	Size
1	Apartment	Kaskitayo	237 units
2	Hotel Comples	104 Street - Calgary Trail	200 - 600 units
3	Apartment	53 Avenue - Riverbend Road	92 units
4	Apartment	149 Street - 51 Avenue	116 units
5	Apartment	28 Avenue - 116 Street	60 units
6	Senior Citizen Home	110 - 111 Street - 52-53 Avenue	153 units
7	Argyll Motor Inn	99 Street - Argyll Road	192 units
8	Research Park	South Edmonton	166 Acres
9	Apartment	Ermineskin	84 units
10	Apartment	Ermineskin	27 units
11	Apartment	28A Avenue - 105 Street	46 units
12	Apartment	27 Avenue - 105 Street	26 units
13	Apartment	105 Street - 27 Avenue	40 units
14	Kaskitayo House	106 Street - 29 Avenue	54 units
15	Apartment	40 Avenue - 114 Street	38 units
16	Apartment	25 Avenue - 119 Street	66 units

Table 6.8 Continued

S. No.	Name	Address	Size
17	Apartment	Riverbend Road - 53 Avenue	101 units
18	Apartment	27 Avenue - Saddleback Road	348 units
19	Apartment	112 Street - 28 Avenue	116 units
20	Apartment	111 Street - Saddleback Road	308 units
21	Office and Warehouse	65 Avenue - 103 Street	10,000 sq. feet
22	Ermineskin House	29 Avenue - 106 Street	44 units
23	D.D.D.D. Apartments	119 Street - 25 Avenue	204 units
24	Office Building	56 Avenue - Riverbend Road	50,000 sq. feet
25	Office	116 Street - 28 Avenue	30,000 sq. feet
26	Warehouse	5304 - 93 Street	-
27	Office	6603 - 99 Street	-

Table 6.9 Forecast Allocation of Business Lines in the Lendrum Switching Center Area

Switching Center Lendrum Business Forecast 530 lines

Module	Area sq. miles	Density lines per sq. mile	Growth Potential	Forecast
A	4.04	36	.04	21
B	2.3	329	.05	26
C	1.53	191	.07	37
D	1.06	324	.06	31
E	1.85	297	.10	53
F	.48	322	.08	42
G	.40	258	.10	53
H	.36	286	.04	21
I	1.47	351	.15	79
J	2.69	127	.07	37
K	.63	136	.05	26
L	.4	430	.07	37
M	1.84	187	.06	31
N	1.46	212	.06	36

Table 6.10 Forecast Allocation of Residential Lines in the Lendrum Switching Center Area

Switching Center Lendrum   Residential Forecast 2000 Lines

Module	Area (sq. miles)	Density (lines per sq. mile)	Growth Potential	Forecast
A .	4.04	172	.01	20
B	2.3	1568	.01	20
C	1.53	911	.46	920
D	1.06	1547	.23	460
E	1.85	1418	.01	20
F	.48	1537	.01	20
G	.40	1230	.01	20
H	.36	1366	.02	40
I	1.47	1673	.06	120
J	2.69	609	.12	240
K	.63	650	.01	20
L	.40	2050	.02	40
M	1.84	891	.02	40
N	1.46	1010	.01	20

$a=0.0214099$, $k= 31,305$, and $b=10.83377$

The saturation level is around 31,305 lines. The critical point has an ordinate equal to k/2 i.e. 15652. The critical value occurred around March 1972. The saturation starts taking place around the year 2004.

Taking y0 equal to 24,296 lines as the origin and using equation 5.12 which now has the numerical form:

$$Vy= 0.0214099y - 0.0000006839\, y^2,$$

the forecast figures were arrived at and are shown in Appendix D.

6.2 Model Testing

The usefulness of a forecasting model must be judged not only by how close the forecasts came to actual observations, but also by objectives such as:

(1) cost to operate;

(2) flexibility to accomodate changes; and

(3) availability of the forecasts.

The actual observations for the Lendrum switching center area were not available for the period September 1977 to August 1978. The yearly forecasts of the demand could not, therefore, be compared with the actual. However , the actual observations for the period September 1977 to February 1978 were available. The forecasts for the six months during this period were compared. Figures 6.2 and

6.3 show the forecast versus the actual for residential and business respectively. The business forecast appears to be close to the values observed. Business growth was expected to continue at the historical rate. The residential forecast is also close to the actuals. However, on the basis of the Box-Jenkins model alone it would have been on the negative side, even though the forecast model was most adequate. These results strongly suggest using a combination of forecasting techniques. The time series analysis forecast combined with the opinion polling forecast give the best results. The cumulative demand is compared in the Table 6.11.

If the company maintains good records, the available data can be directly fed into the computer, thus avoiding the initial preparation of data. Actual construction and maintenance records by outside plant personnel can be recorded to sample the opinions and keep abreast of plans. This information is incorporated into the growth potential factor to acknowledge the regional growth differentials.

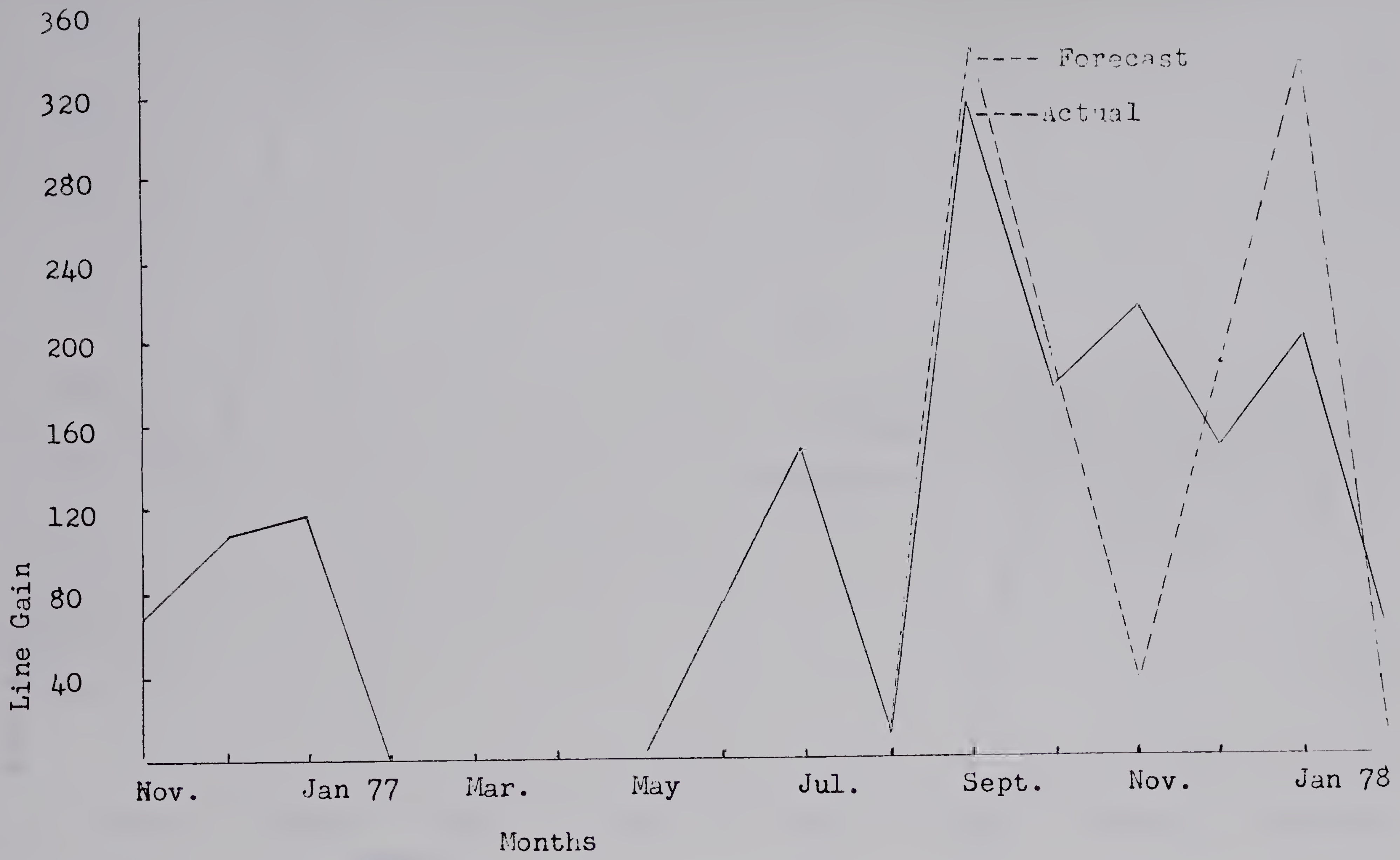

Figure 6.2 Comparison of Forecast of Residential Line Gain with the Actuals

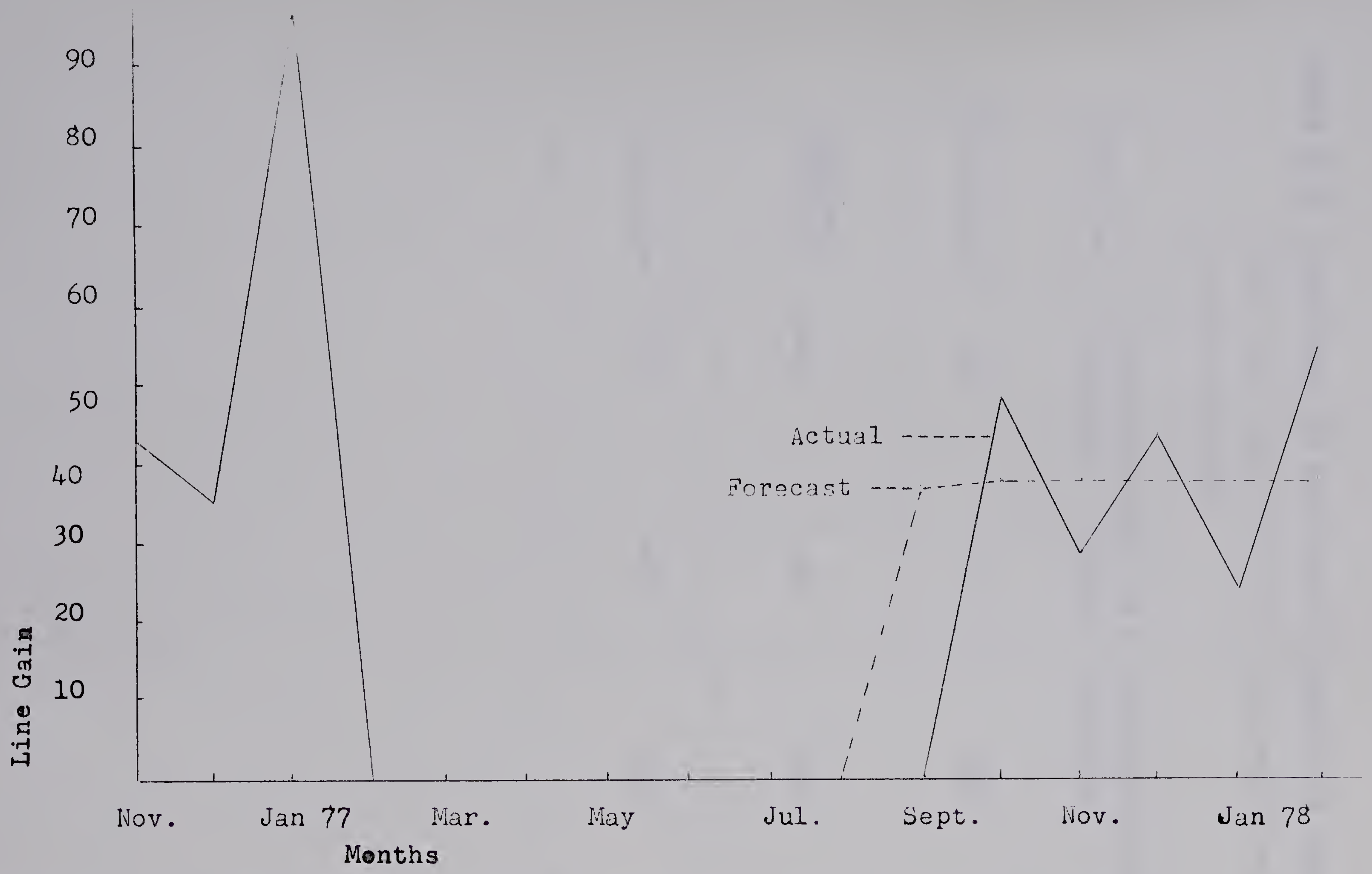

Figure 6.3 Comparison of Forecast of Business Line Gain with the Actuals

Table 6.11 Comparison of Forecast of Cumulative Additions to Lines with the Actuals for the period September 1977 to February 1978.

Technique	Business(Actual 201)		Residential(Actual 1131)	
	Forecast	Error	Forecast	Error
Box-Jenkins	228	+27	1095	-36
Opinion Polling	300	+99	1400	+269
Composite	228	+28	1120	-11

CHAPTER VII

SUMMARY AND CONCLUSIONS

In the design of a computerized model for forecasting telecommunications demand within an integral system (i.e. a city) components and characteristics of the telecommunications demand were studied.

The fundamental purpose was to develop a system to forecast annual line growth. Various systems for forecasting demand as used by various telecommunications companies were analyzed considering the nature of the telecommunications demand . A system using the switching center area as the basic building block was selected for design. The system was further divided into four subsystems, each of which was individually designed. For every system or subsystem various alternatives were considered and the decision criteria were formulated to arrive at the best alternative. The detailed design yielded a model which forecasts residential and business demand individually for each switching center area using a combination of quantitative (time series analysis) and qualitative (opinion polling) techniques. For the long range forecast a maximum development level is forecast using

a logistic model.

The major conclusions arrived at through this study are as follows:

(1) Business and residential components of telecommunications demand must be subjected to separate analysis, as they have distinct characteristics. Residential demand depicts a distinct seasonality, whereas business demand is non-seasonal. The latter follows general movements of the local and national economy.

(2) The short range quantitative forecasting models need not be the same for all the switching center areas, both for business and residential categories. The model adequate for the particular series must be used.

(3) A combination of quantitative and qualitative approaches is a better approach than any single method. A composite forecast is usually more accurate as it retains more advantages and information. Time series analysis makes highly effective use of historical demand patterns. As such it is a very efficient technique for routine short term prediction. However, it fails to predict turning points. To ascertain when the first home will be built in a given area, qualitative techniques such as opinion polling must be used. A combination of two forecasts should be

arrived at using appropriate weightings.

(4) Long range forecasts are difficult to make with time series analysis, as the confidence limits become too wide to have a meaning. Such models are based on the assumption that past patterns will continue into the future, which is less likely to be valid in the long run.

(5) The long range yearly forecasts are too sensitive, and less pertinent for planning purposes than the forecast of ultimate demand in a switching center area. The maximum development level of a switching center area is forecast using a logistic model.

(6) The short range forecast for each switching center area in business as well as residential categories, can be allocated to individual uniform modules within a switching center area. A micro-forecast is arrived at using the concept of growth potential which takes care of regional differences in growth. A growth potential factor is calculated using the past growth pattern, and is modified subjectively to take care of future development plans.

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Appendix A

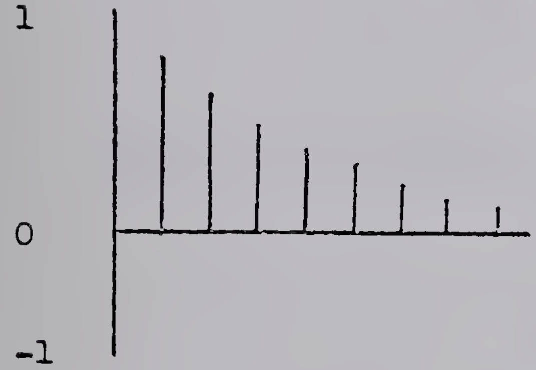
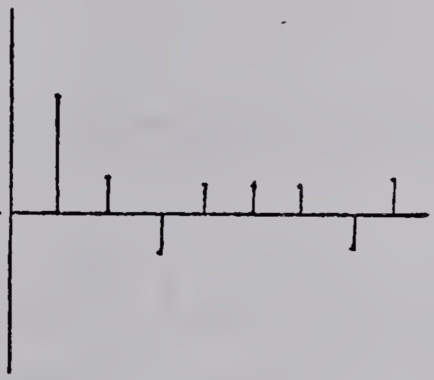
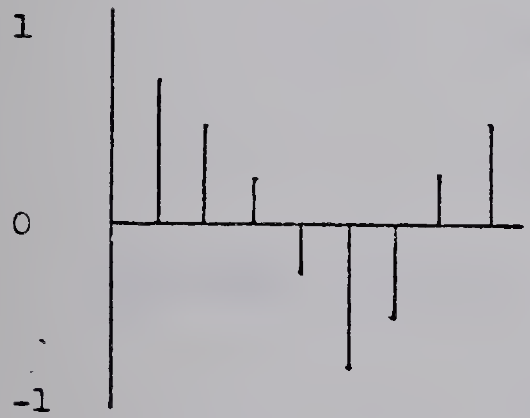
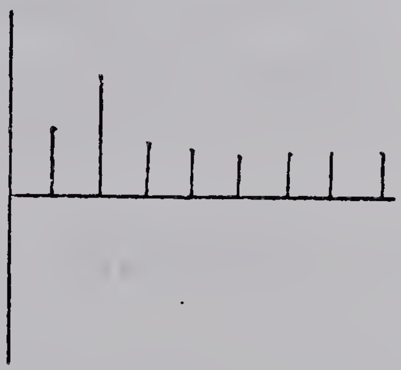
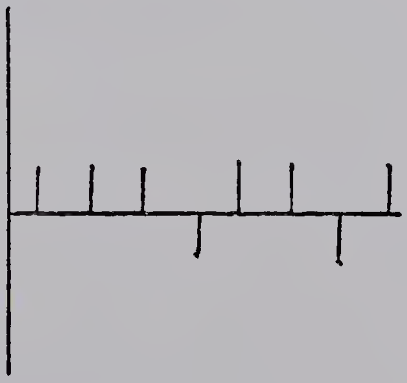
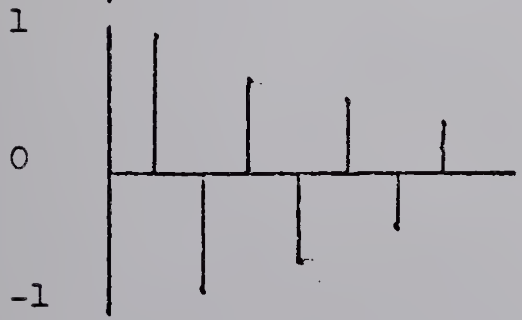
Autocorrelation	Partial Autocorrelation	Relationship	Tentative Model
		ARIMA(1,0,0)	$(1-\phi_1 B)Y_t=a_t$
		ARIMA(2,0,0)	$(1-\phi_1 B-\phi_2 B^2)Y_t=a_t$
		ARIMA(0,0,2)	$Y_t=(1-\theta_1 B-\theta_2 B^2)a_t$
		ARIMA(1,0,0)	$(1-\phi_1)Y_t=a_t$

Figure 1. Identification Process Examples.

Appendix A

Sample Autocorrelation factor r_k is given by:

$$r_k = \frac{\sum_{t=1}^{n-k} (Y_t-\bar{Y})(Y_{t+k}-\bar{Y})}{\sum_{t=1}^{n} (Y_t-\bar{Y})^2} \quad ,k = 0,1, \ldots .k$$

Sample Partial Autocorrelation factor Akk is given by:

$$Akk = \begin{cases} r_1 & k = 1 \\ \dfrac{r_k - \sum_{j=1}^{k-1} A_{k-1,j}\, r_{k-j}}{1 - \sum_{j=1}^{k-1} A_{k-1,j}\, r_j} & , k = 2,3, \ldots .\ k \end{cases}$$

where $Akj = A_{k-1,j} - A_{kk}\, A_{k-1,k-j}$

$$j = 1,2,\ldots ..k-1$$

Appendix B

INPUT YOUR SERIES ** DATA

MAX	MIN	MEAN	VAR.	S.E.	N
96.000	.000	42.806	535.428	4.156	31

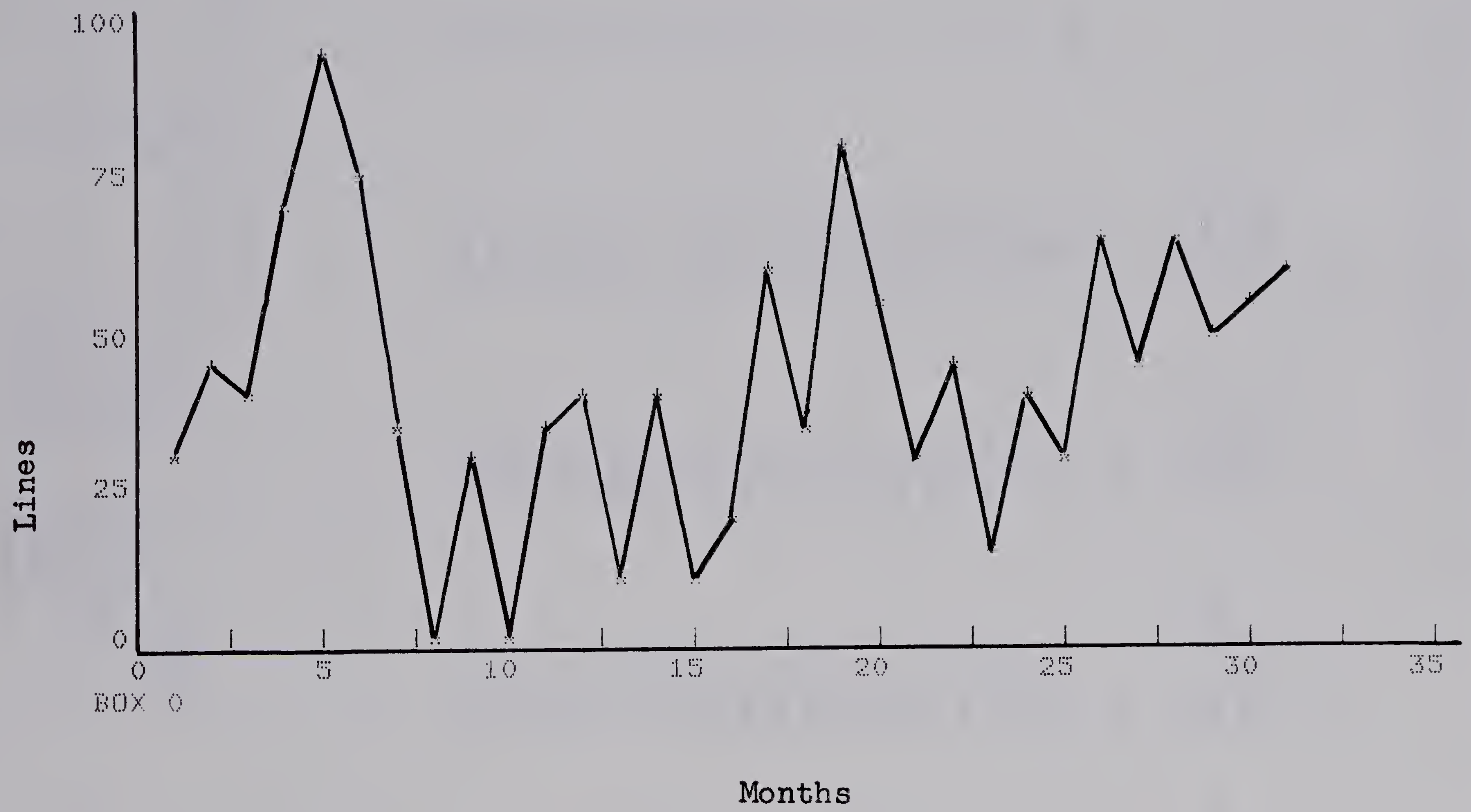


Figure 1. Residential Gain for a Typical Switching Center Area

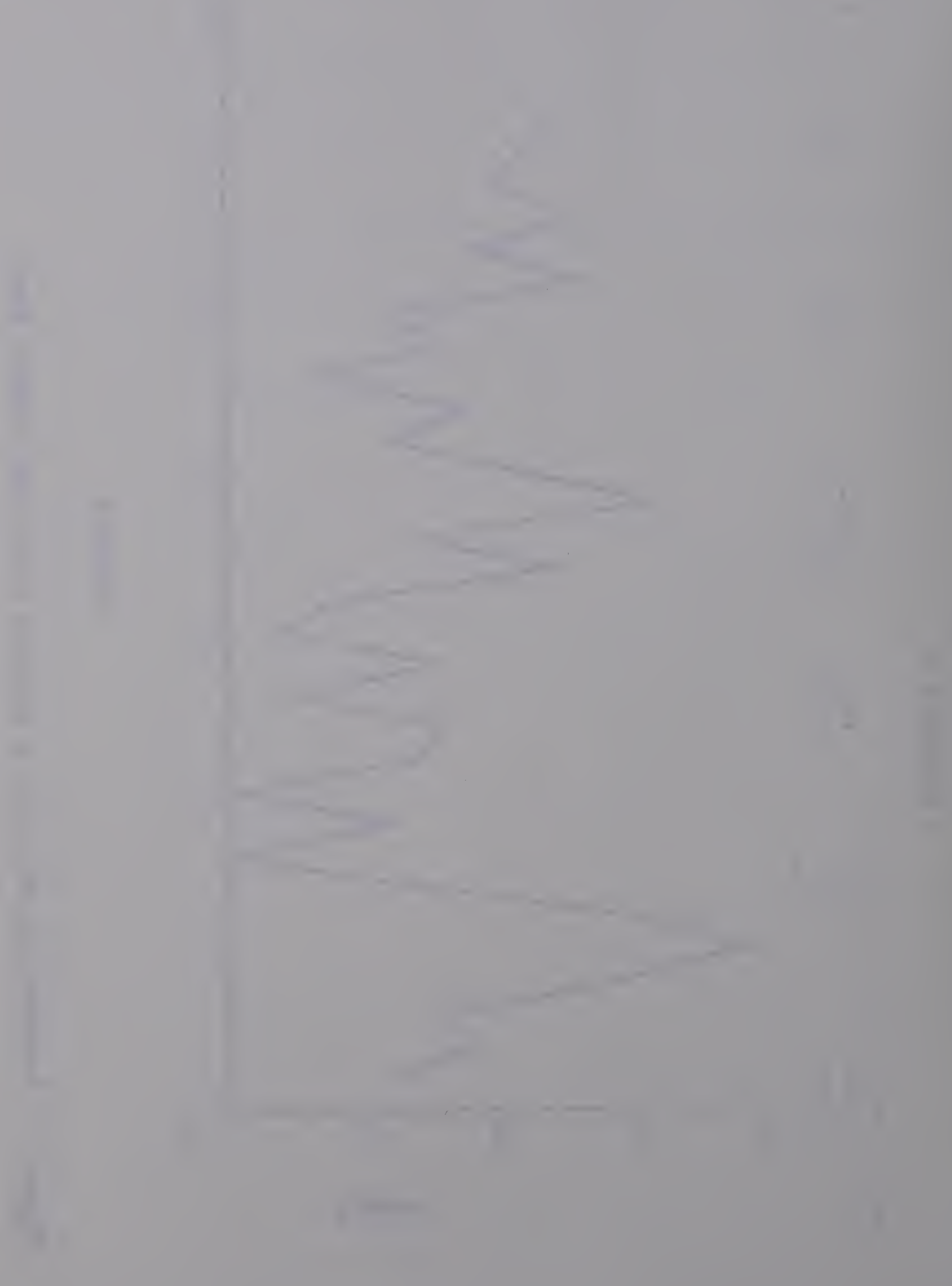


Table 1. Autocorrelation and Partial Autocorrelation Factors for the Residential Gain

DIFF	LAG	0	1	2	3
MEAN		42.806	1.000	¯.276	.786
S.E.		4.156	4.838	8.399	16.030
VAR.		535.428	702.069	2045.778	7194.841
D.F.		31	30	29	28
APPROX. SE(ACF)		.180	.183	.186	.189
	1	.350	¯.412	¯.700	¯.777
	2	.238	.159	.258	.330
	3	¯.075	¯.018	.083	.081
	4	¯.360	¯.431	¯.384	¯.370
	5	¯.056	.274	.415	.443
	6	¯.139	¯.190	¯.282	¯.315
	7	.035	.148	.115	.104
	8	¯.016	.111	.108	.105
	9	¯.155	¯.177	¯.207	¯.218
	10	¯.133	.063	.180	.212
	11	¯.151	¯.177	¯.156	¯.150
	12	.028	.045	.056	.059
	13	.095	.056	.023	.026
	14	.163	.056	¯.060	¯.094
	15	.109	.183	.169	.171
	16	¯.125	¯.175	¯.217	¯.221
	17	¯.095	.128	.198	.210
	18	¯.278	¯.185	¯.153	¯.156
	19	¯.160	¯.008	.054	.083
	20	¯.084	.009	¯.007	¯.031

DEGREE OF DIFFERENCE ** 1

THE APPROXIMATE S.E. IS : 0.18257

LAG	PACF	PACF/SE
1	¯0.41218	¯2.2576
2	¯0.012955	¯0.070955
3	0.045271	0.24796
4	¯0.52914	¯2.8982
5	¯0.17317	¯0.94849

Table 2. Specification and Estimation Process

```
   ***SPECIFICATION SECTION***

CHOOSE DEGREE OF DIFFERENCE          ** 1
INPUT NUMBER OF AR TERMS             ** 1
INPUT DESIRED LAGS FOR AR TERMS      ** 1
INPUT NUMBER OF MA TERMS             ** 2
INPUT DESIRED LAGS FOR MA TERMS      ** 1 4
INPUT A 1 FOR A MEAN ,0 IF NOT       ** 0
INPUT PERIOD OF SEASONALITY          ** 0

STATISTISTICS ON THE W SERIES
     MAX        MIN         MEAN        VAR.        S.E.       N
   46.000    ¯39.000       1.000     702.069       4.838      30

   ***INITIAL FITTING SECTION***

INITIAL AR ESTIMATES:         ¯0.63565
INITIAL MA ESTIMATES:        ¯0.25197 0 0 0.76177

   ***FINAL FITTING SECTION***

CONVERGENCE IS ASSUMED AT ITERATION NO: 5
NUMBER OF ITERATIONS PERFORMED        : 6
THE RESIDUAL VARIANCE IS              :  346.05

FINAL AR ESTIMATES          ¯0.51918
FINAL MA ESTIMATES          ¯0.0080358 0.87212
```

```
***DIAGNOSTIC SECTION ON RESIDUALS***
THE CHI SQUARE STATISTIC = 7.7996  WITH 22 DEGREES OF FREEDOM
THE LEVEL OF SIGNIFICANCE = 0.99765

INPUT ORDER OF DIFFERENCE FOR PLOT OR 999 ** 0
```

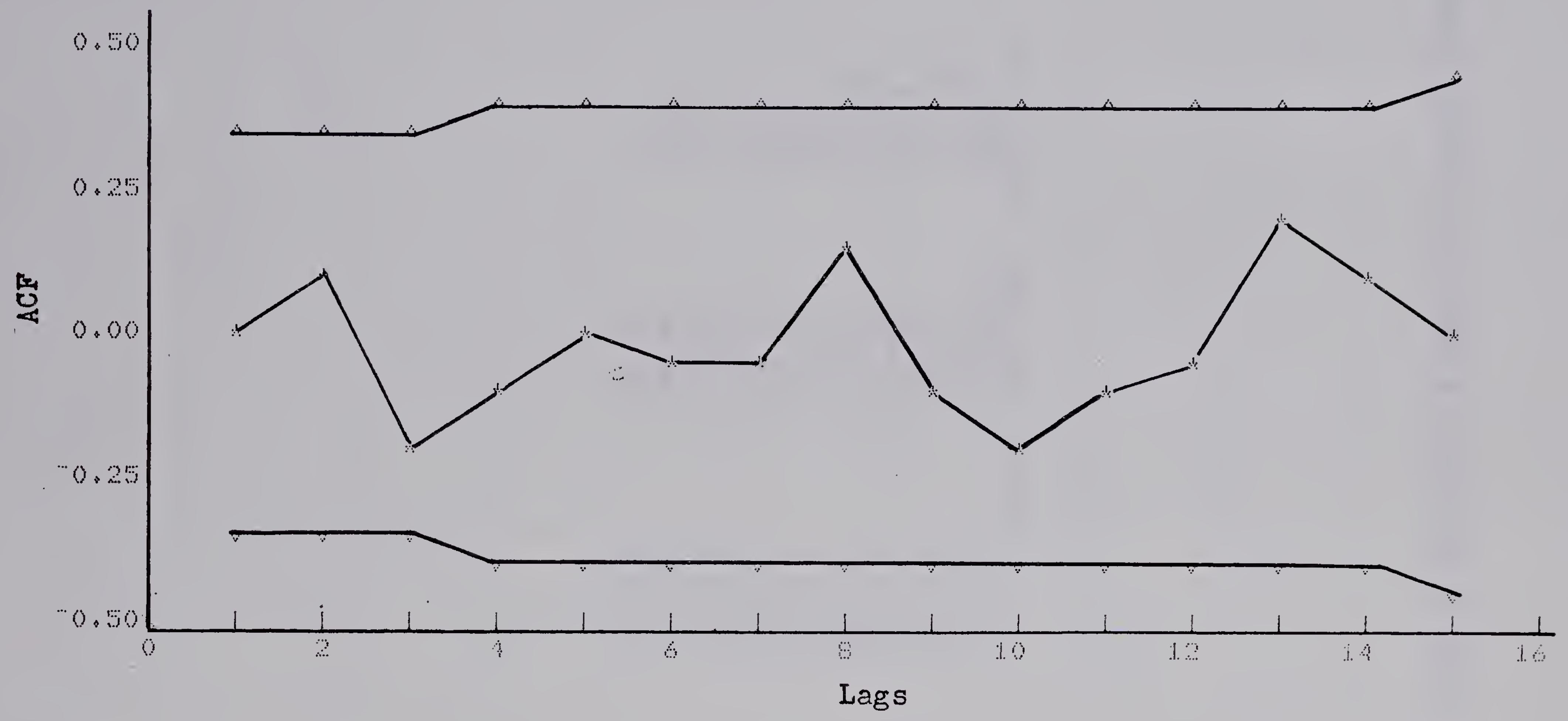


Figure 2. The Autocorrelogram for the Residuals

Table 3. Forecast based on the model specified in Table 2.

	90 PERCENT CONFIDENCE LIMITS		
OBS	LOWER	FORECAST	UPPER
32	21.427	52.032	82.636
33	24.629	58.726	92.823
34	¯3.147	38.030	79.206
35	5.417	50.733	96.048
36	¯1.508	44.165	89.838
37	1.350	47.561	93.771
38	¯.408	45.805	92.018
39	.340	46.713	93.086
40	¯.177	46.243	92.663
41	¯.031	46.486	93.003
42	¯.225	46.361	92.946
43	¯.243	46.425	93.093

Appendix C

Computer Program for Logistic Curve Parameter Estimation

```
      REAL*8  YFO,YO,Y(200),P,Q
      REAL*8  SDY/0.0/,SINY/0./,INY ,SB/0./
      REAL*8  SY/0.0/,SR/0./,SYSQ/0.0/,B(8)
      INTEGER IYM(200), MA(200)
C
C***** READ THE OBSERVATIONS(TOTAL LINES), THE FORECAST *****
C***** ORIGIN AND THE NUMBER OF OBSERVATIONS*****
C
      READ (5,19)YO,YFO,N
      READ(3,10) (Y(I),I=1,N)
      WRITE(6,22)
      DO 11 I=1,N
C
C***** CALCULATE PARAMETERS OF THE NORMAL EQUATION*****
C
      DY=Y(I-YO
      INY=1.0/Y(I)
      R=DY*INY
      YSQ=Y(I)*Y(I)
      SY=SY+Y(I)
      SDY=SDY+DY
      SINY=SINY+INY
      SR=SR+R
      SYSQ=SYSQ+YSQ
      WRITE(6,12)Y(I),DY,INY,R,YSQ
   11 YO=Y(I)
C
C***** WRITE THE PARAMETERS OF THE NORMAL EQUATION*****
C
      WRITE(6,25) SY,SDY,SINY,SR,SYSQ
      WRITE(6,44)
C
C***** SOLVE THE NORMAL EQUATION USING GAUSS ELIMINATION ****
C***** METHOD *****
C
      Q1=SR*SY-SDY*DFLOAT(N-1)
      Q2=SY**2-SYSQ*DFLOAT(N-1)
      Q=Q1/Q2
      P1=SR-SY*Q
      P=P1/DFLOAT(N-1)
      A=P
      RK=-P/Q
      DO 21 I=1,7,2
      NN=I*N/8
      B1=RK/(Y(NN)-1.0
```

```
      B2=EXP(A*FLOAT(I*N/8))
      B(I)=B1*B2
   21 SB=SB+B(I)
      B(8)=SB/4
C
C***** WRITE THE LOGISTIC PARAMETERS*****
C
      IK=IFIX(RK)
      WRITE(6,33)A,Q,B(5)
      WRITE(6,34)IK
      YM=YFO
C
C***** OUTPUT THE LOGISTIC FORECAST*****
C
      WRITE(6,55)
      DO 5 I=1,200
      X=A*YM+Q*YM**2.
      YM=YM+X
      IX=IFIX(X)
      IYM(I)=IFIX(YM)
    5 MA(I)=I
      WRITE (6,15)(MA(I),IYM(I),I=1,N)
   22 FORMAT('1',35X,'PARAMETERS OF THE NORMAL EQUATION',
     1//,9X,'OBSERVATIONS',7X,'CHANGE',2X,'INVERSE
     1OBSERVATIONS '
     1,6X,'R=DY/Y',9X,'OBSERVATION SQUARES',//)
   12 FORMAT(4X,F14.1,F14.1,1X,F20.15,1X,F20.15,1X,F20.1)
   25 FORMAT(////,40X,'SUMMATIONS OF THE ABOVE',//
     1/,7X,F14.2,F14.1,F20.15,F20.15,2X,F20.2)
   10 FORMAT(12F8.1)
   44 FORMAT(//,10X,'PARAMETERS OF THE LOGISTIC CURVE ARE:')
   33 FORMAT(//,10X,'A=',2X,F14.12,2X,'Q=',2X,F14.12,2X,'B=',
   34 FORMAT(//,10X,'MAXIMUM  DEVELOPMENT  LEVEL  OF',//,
     1SWITCHING CENTER AREA IS', 10X,I6,2X,'LINES')
   19 FORMAT(2F7.1,I3)
   55 FORMAT(//,10X,'FORECAST BASED ON LOGISTIC ASSUMPTION',/
   15 FORMAT(4(10X,I3,2X,I6))
      STOP
      END
```

Appendix D

Table 1. Cumulative Growth of Total Lines for Lendrum Switching Center Area

2797	2814	2832	2858	2859	2886	2950	2990	3092	3146	3185	3225
3259	3305	3387	3451	3536	3591	3727	3828	3997	4477	4526	4572
4603	4815	5038	5089	5126	5177	5247	5325	5468	5509	5616	5691
5762	6431	6529	6632	6683	6752	6755	6854	6991	7101	7138	7155
7177	7199	7299	7343	7422	7550	7717	7875	8197	8362	8465	8880
8908	8944	9014	9116	9212	9328	9376	9593	9995	10134	10228	10323
10394	10776	11130	11190	11215	11301	11378	11492	11733	11834	11889	11927
11965	12015	12079	12103	12054	12155	12349	12478	12731	12834	12871	12934
12993	13020	13614	13561	13580	13577	13687	13690	13919	14081	14149	14202
14340	14408	15805	15916	15935	16009	16095	16233	16550	16784	16910	17070
17444	17646	18502	18620	18667	18795	18960	19284	19803	19851	19859	19899
20030	20614	20704	20630	20591	20599	20640	20950	21363	21588	21700	21721
21819	21865	21922	21798	21887	21936	22033	22257	22509	22736	22946	23083
23251	23361	23426	23404	23558	23609	23676	23722	23946	24083	24194	24336
24549	24267	24296	24323	24364	24484	24675	24726	25071	25331	25576	25769
25996	26115										

Long Range Forecast

PARAMETERS OF THE NORMAL EQUATION

OBSERVATIONS	CHANGE	INVERSE OBSERVATIONS	R=DY/Y	OBSERVATION SQUARES
2797.0	0.0	0.000357525920629	0.0	7823209.0
2814.0	17.0	0.000355366027008	0.006041221320629	7918596.0
2832.0	18.0	0.000353107344633	0.006355930119753	8020224.0
2858.0	26.0	0.000349895031491	0.009097270667553	8168164.0
2859.0	1.0	0.000349772647779	0.000349772628397	8173881.0
2886.0	27.0	0.000346500346500	0.009355507791042	8328996.0
2950.0	64.0	0.000338983050847	0.021694913506508	8702500.0
2990.0	40.0	0.000334448160535	0.013377923518419	8940100.0
3092.0	102.0	0.000323415265201	0.032988354563713	9560464.0
3146.0	54.0	0.000317863954228	0.017164651304483	9897316.0
3185.0	39.0	0.000313971742543	0.012244895100594	10144225.0
3225.0	40.0	0.000310077519380	0.012403100728989	10400625.0
3259.0	34.0	0.000306842589751	0.010432645678520	10621081.0
3305.0	46.0	0.000302571860817	0.013918302953243	10923025.0
3387.0	82.0	0.000295246530853	0.024210214614868	11471769.0
3451.0	64.0	0.000289771080846	0.018545348197222	11909401.0
3536.0	85.0	0.000282805429864	0.024038460105658	12503296.0
3591.0	55.0	0.000278473962684	0.015316065400839	12895281.0
3727.0	136.0	0.000268312315535	0.036490473896265	13890529.0
3828.0	101.0	0.000261233019854	0.026384532451630	14653584.0
3997.0	169.0	0.000250187640731	0.042281709611416	15976009.0
4477.0	480.0	0.000223363859727	0.107214629650116	20043520.0
4526.0	49.0	0.000220945647371	0.010826334357262	20484672.0
4572.0	46.0	0.000218722659668	0.010061241686344	20903184.0
4603.0	31.0	0.000217249619813	0.006734736263752	21187600.0
4815.0	212.0	0.000207684319834	0.044029075652361	23184224.0
5038.0	223.0	0.000198491464867	0.044263593852520	25381440.0
5089.0	51.0	0.000196502259776	0.010021612048149	25897920.0
5126.0	37.0	0.000195083886071	0.007218100130558	26275872.0
5177.0	51.0	0.000193162062971	0.009851261973381	26801328.0
5247.0	70.0	0.000190585096245	0.013340953737497	27531008.0
5325.0	78.0	0.000187793427230	0.014647886157036	28355616.0
5468.0	143.0	0.000182882223848	0.026152156293392	29899024.0
5509.0	41.0	0.000181521147214	0.007442366331816	30349072.0
5616.0	107.0	0.000178062678063	0.019052702932550	31539456.0
5691.0	75.0	0.000175716042875	0.013178702443838	32387472.0

23722.0	46.0	0.000042154961639	0.001939128153026	562733056.0
23946.0	224.0	0.000041760628080	0.009354379028082	573410816.0
24083.0	137.0	0.000041523066063	0.005688659846783	579990784.0
24194.0	111.0	0.000041332561792	0.004587911069393	585349632.0
24336.0	142.0	0.000041091387245	0.005834974348545	592240896.0
24549.0	213.0	0.000040734856817	0.008676521480083	602653184.0
24267.0	-282.0	0.000041208225162	-0.011620718985796	588887040.0
24296.0	29.0	0.000041159038525	0.001193612115458	590295552.0
24323.0	27.0	0.000041113349505	0.001110060373321	591608320.0
24364.0	41.0	0.000041044163520	0.001682810485363	593604352.0
24484.0	120.0	0.000040842999510	0.004901159554720	599466240.0
24675.0	191.0	0.000040526849037	0.007740627974272	608855552.0
24726.0	51.0	0.000040443258109	0.002062606159598	611374848.0
25071.0	345.0	0.000039886721710	0.013760916888714	628555008.0
25331.0	260.0	0.000039477320279	0.010264102369547	641659392.0
25576.0	245.0	0.000039099155458	0.009579289704561	654131712.0
25769.0	193.0	0.000038806317669	0.007489617913961	664041216.0
25996.0	227.0	0.000038467456532	0.008732110261917	675791872.0
26115.0	119.0	0.000038292169251	0.004556767642498	681993216.0

SUMMATIONS OF THE ABOVE

2452748.00	23318.0	0.020629083172334	2.197577905040816	42684548323.00

PARAMETERS OF THE LOGISTIC CURVE ARE:

A= 0.021409895271 Q= -.000000683973 B= 10.8377762

MAXIMUM DEVELOPMENT LEVEL OF

THE SWITCHING CENTER AREA IS 31302 LINES

Table 2. Forecast Based On Logistic Assumption (Forecast Origin September 1978)

1	24527	2	24640	3	24752	4	24863
5	24973	6	25081	7	25188	8	25293
9	25397	10	25500	11	25601	12	25701
13	25799	14	25896	15	25992	16	26086
17	26179	18	26271	19	26361	20	26451
21	26538	22	26625	23	26710	24	26794
25	26876	26	26958	27	27038	28	27117
29	27194	30	27271	31	27346	32	27420
33	27493	34	27564	35	27635	36	27704
37	27772	38	27839	39	27905	40	27970
41	28034	42	28097	43	28158	44	28219
45	28278	46	28337	47	28394	48	28451
49	28506	50	28561	51	28614	52	28667
53	28718	54	28769	55	28819	56	28868
57	28916	58	28963	59	29010	60	29055
61	29100	62	29143	63	29187	64	29229
65	29270	66	29311	67	29351	68	29390
69	29428	70	29466	71	29503	72	29539
73	29575	74	29610	75	29644	76	29678
77	29711	78	29743	79	29775	80	29806
81	29836	82	29866	83	29896	84	29924
85	29953	86	29980	87	30007	88	30034
89	30060	90	30085	91	30111	92	30135
93	30159	94	30183	95	30206	96	30228
97	30251	98	30272	99	30294	100	30315
101	30335	102	30355	103	30375	104	30394
105	30413	106	30431	107	30450	108	30467
109	30485	110	30502	111	30518	112	30535
113	30551	114	30566	115	30582	116	30597
117	30612	118	30626	119	30640	120	30654
121	30668	122	30681	123	30694	124	30707
125	30719	126	30732	127	30744	128	30755
129	30767	130	30778	131	30789	132	30800
133	30810	134	30821	135	30831	136	30841
137	30851	138	30860	139	30869	140	30879
141	30887	142	30896	143	30905	144	30913